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Fire Testing Laboratory

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TEST REPORT

for

Concrete Reinforcing Steel Institute

933 N. Plum Grove Road
Shaumburg, IL 60173

Standard Test Method for
Fire Tests of Building Construction and Materials
ASTM E119 – 16a

Test Report No: FC-891

Assignment No: K-1193

Subject Material: Steel Reinforced Concrete Slab with Low Profile Recycled Plastic Voids

Test Date: June 15, 2017

Report Date: July 14, 2017

Prepared by: _____

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Revision Summary

DATE	SUMMARY
July 14, 2017	Original issue date. Original NGCTS report FC-891.

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Introduction

The Fire Testing Laboratory of NGC Testing Services (NGCTS) conducted testing for Concrete Reinforcing Steel institute (CRSI) on a load bearing, full-scale voided concrete slab assembly. The purpose of the test was to evaluate the fire resistance properties of the voided concrete slab assembly when exposed to fire according to ASTM E119 test conditions. This evaluation was conducted on June 15, 2017.

This report presents the results of the fire test conducted according to ASTM E119-16a (Standard Test Methods of Fire Tests of Construction and Building Materials). This document contains a description of the assembly evaluated, procedures used, and the test results. Note that the results listed apply only to specimens tested, in the manner tested, and not to the entire production of this or similar specimens.

Test Assembly

The test assembly consisted of a nominal 14 ft. x 18 ft. x 8 in. steel reinforced concrete slab containing a “grid” of low profile recycled plastic voids, supplied by the client. A concrete contractor, hired by NGCTS, provided the test assembly’s concrete mix design (5000 psi) and steel reinforcement (#4 rebar), and performed the pour and finishing of the voided concrete slab.

The recycled plastic voids were in the shape of flattened spheres, contained in steel cages. The recycled plastic voids, which measured nominally 13 in. in diameter and 4 in. high, were spaced approximately 13-3/4 in. on center within the steel cages. A total of 130 (10 x 13 grid) recycled plastic voids were utilized in the concrete slab test assembly.

Multiple cages of the recycled plastic voids, forming the 10 x 13 grid, were set directly on top of a rebar mat, consisting of #4 rebar spaced at 12 inches on center. A second rebar mat, also consisting of #4 rebar spaced at 12 inches on center, was placed on top of the recycled plastic void cages. The cages were secured in place to the top and bottom rebar mats using wire ties. A 5000 psi concrete mix design was poured over the recycled plastic void and rebar mat assembly to an 8 in. nominal thickness. The recycled plastic void cages were positioned in the center of the concrete slab in order to provide a nominally 13 in. wide solid (non-voided) concrete perimeter.

The voided concrete slab test assembly was poured on February 9, 2017. After a 28 day cure time, the voided concrete slab test assembly was removed from its form and placed within one of NGCTS’ test frames, where it remained to dry to moisture content of less than 75% prior to testing. The moisture content of the voided concrete slab was measured to be 69% (Wagner Rapid RH® reader) when it was tested on June 15, 2017.

Testing and Evaluation Methods

NGCTS' full-scale (14' x 18') horizontal furnace was utilized for the fire endurance test. The furnace's combustion chamber was fitted with eighty uniformly located natural gas burners providing an even heat flux distribution across the test assembly's exposed surface.

Furnace temperature control was maintained with the use of sixteen (16) 18 AWG Type K insulated thermocouples enclosed in a sealed protection tube and distributed evenly within the furnace chamber. The furnace thermocouples were located 12 inches below the exposed face of the test specimen. Furnace temperatures were maintained in accordance with the ASTM E119 time-temperature curve, and were measured and recorded at 15 second intervals. The furnace interior temperature during the test was controlled such that the area under the time-temperature curve was within 5% of the corresponding area under the standard E119 time-temperature curve. The recorded furnace thermocouple data is presented (in 1 minute intervals) in Appendix A.

Unexposed surface temperatures of the test assembly were measured with a total of nine (9) 20 AWG Type J thermocouples. The unexposed surface temperatures were measured and recorded at 15 second intervals. The (9) thermocouples were strategically located about the assembly's unexposed surface in accordance with the requirements of section 7.3.1.2 of ASTM E119. The unexposed surface thermocouples were placed under 6 in. x 6 in. x 0.40 in. thick dry, felted pads. Unexposed surface temperatures were measured and recorded at 15 second intervals, as shown in Figure 3. The recorded unexposed surface thermocouple data is presented (in 1 minute intervals) in Appendix B.

The voided concrete slab assembly was loaded with a uniformly distributed live load of 80 PSF, per client specification. The live load was applied on the assembly using sixteen (16) evenly spaced steel tanks filled with water. The water-filled steel tanks were applied to the assembly approximately 20 minutes prior to the start of the fire test.

The vertical deflection of the voided concrete slab assembly was measured with three (3) plumb bobs located at the center and quarter points of the north-south centerline. The plumb bobs were attached to wire pulleys and tape measures for recording the resulting deflections.

Throughout the test, observations were made to note the character of the fire and its control, the condition of the exposed and unexposed surfaces, and the development pertinent to the performance of the concrete slab assembly with reference to stability, heat transmission, passage of flame, deformation, and the generation of smoke.

Conditions of Acceptance

Per ASTM E119, the conditions of acceptance for Unrestrained Assembly Classification include the following:

8.6.6.1 The test specimen shall have sustained the applied load during its classification period without developing unexposed surface conditions which will ignite cotton waste.

8.6.6.2 Transmission of heat through the test specimen during its classification period shall not raise the average temperature on its unexposed surface more than 250°F (139°C) above its initial temperature.

7.3.1.4 Where the conditions of acceptance place a limitation on the rise of temperature of the unexposed surface, the temperature end point of the fire-resistance period shall be determined by the average of the measurements taken at individual points; except that if a temperature rise 30% in excess of the specified limit occurs at any one of these points, the remainder shall be ignored and the fire-resistance period judged as ended.

Test Results

The fire test was conducted on June 15, 2017 at the Fire Testing Laboratory of NGC Testing Services (NGCTS), located in Buffalo, NY. The test was witnessed by Mike Mota, a representative of CRSI.

The furnace and unexposed surface thermocouple leads were connected to the data acquisition system and their outputs verified. The laboratory's ambient air temperature was 75°F. At 08:34 am, the furnace was fired and testing commenced.

Character and Distribution of Fire – The furnace chamber fire was luminous and well distributed throughout the test. The furnace temperature conformed to the standard time-temperature curve as outlined in ASTM E119. The furnace interior temperature during the test was controlled such that the area under the time-temperature curve was within 5% of the corresponding area under the standard time- temperature curve (see Figures 1 and 2).

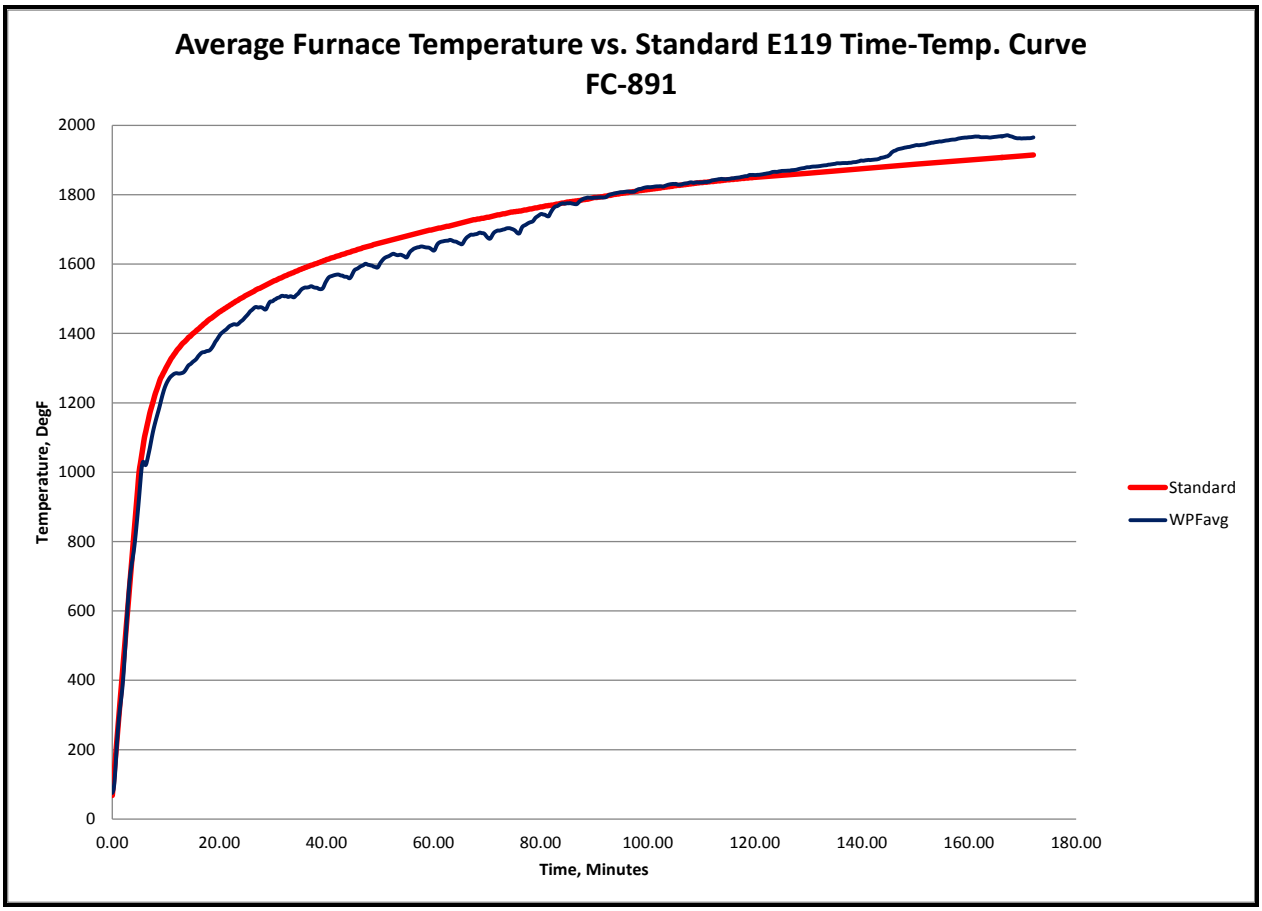

Figure 1 – Average Furnace Temperature vs. E119 Standard Time-Temp. Curve

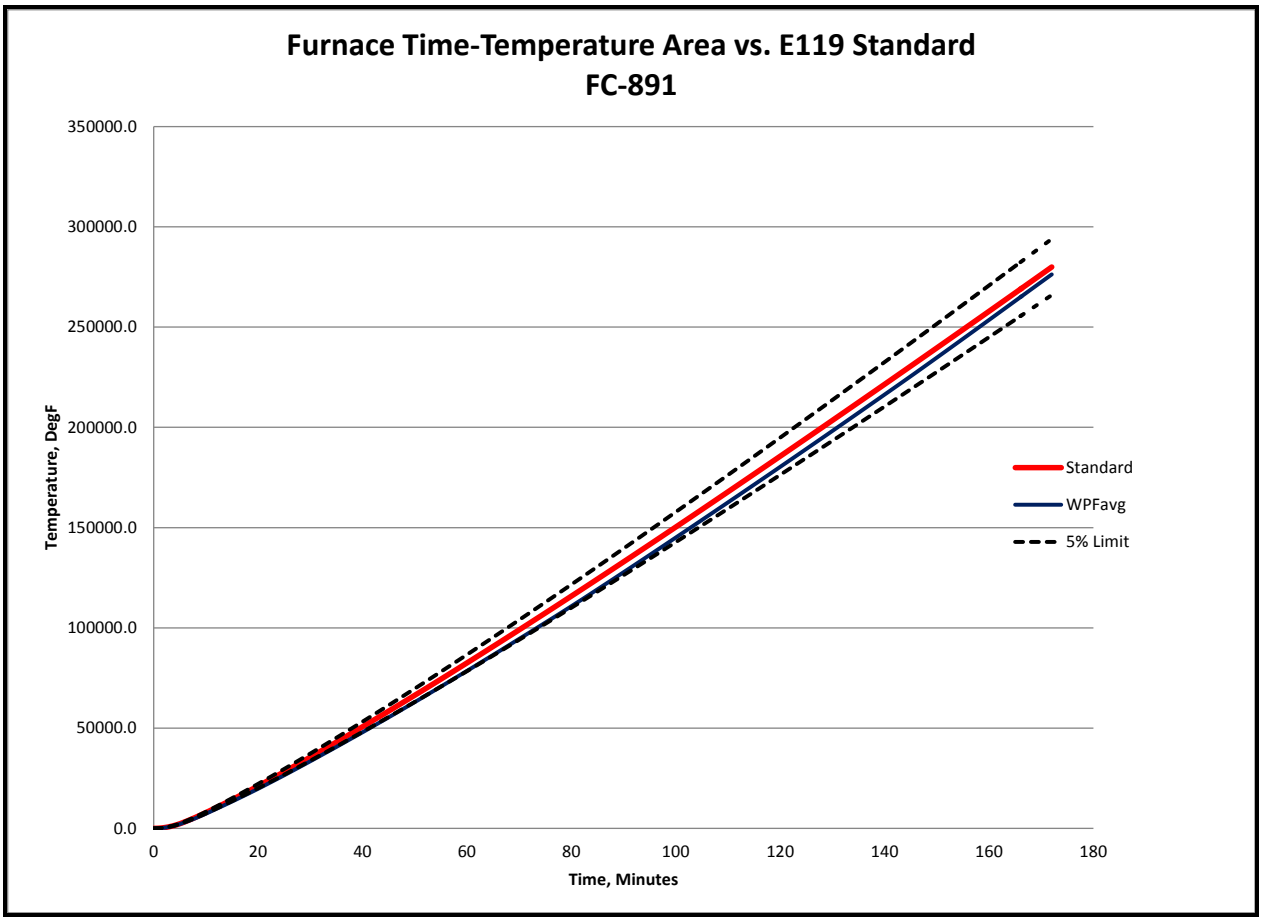

Figure 2 – Furnace Area Under the Curve vs. E119 Standard

Temperatures on the Unexposed Surface – The initial average temperature of the unexposed surface before the test was 74°F; therefore, based on a maximum average temperature rise of 250°F and a maximum individual temperature rise of 325°F (30% in excess of 250°F), the average limiting temperature was 324°F and the individual limiting temperature was 399°F.

Neither the average limiting temperature nor the individual limiting temperature was reached prior to the 2 hour classification period (see Figure 3). At the end of the 2-hour classification period, the average and maximum individual temperatures on the unexposed surface were 188°F and 252°F, respectively. At the request of the client, the test was continued for informational purposes. At 2 hours, 51 minutes, and 45 seconds into the test, individual TC7 exceeded the limiting temperature of 399°F. The test was subsequently terminated after 2 hours, 52 minutes, and 8 seconds.

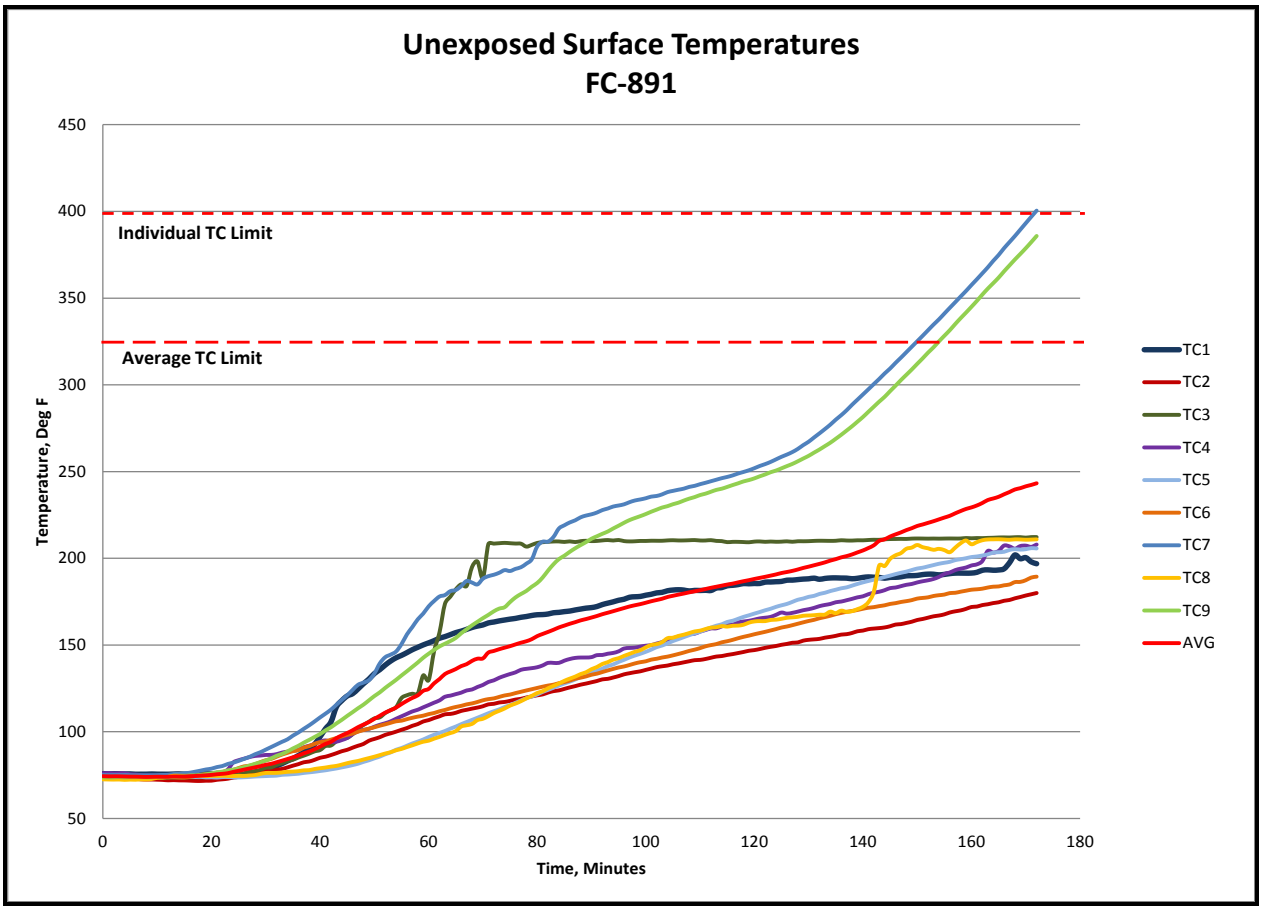

Figure 3 – Individual and Average Unexposed Surface Temperatures

Observations During Fire Test – The following are chronological descriptions of the observations made during the fire test on the exposed and unexposed surfaces.

Test Time (Min:Sec)	Exposed (ES) or Unexposed (US) Side	Observations
1:30	ES	Sporadic spalling of concrete under plastic voids
2:00	ES	Partially exposed plastic voids melting and dripping down onto the furnace chamber floor
5:00	ES	Increased spalling of bottom surface of concrete slab exposing several plastic voids
6:00	ES	Bottom rebar mat exposed in some areas; hanging down
7:30	ES	Black smoke generated from melting plastic voids
22:00	US	Water surfacing on top of unexposed surface

Test Time (Min:Sec)	Exposed (ES) or Unexposed (US) Side	Observations
30:00	ES	Spalling of bottom surface of slab significantly decreased
45:00	US	Black smoke from perimeter corners of test assembly
50:00	--	Furnace viewing port windows blackened; unable to see inside furnace chamber
75:00	US	Flaming around perimeter corners of test assembly; due to increased deflection of concrete slab
171:45	US	TC7 exceeded temp. rise limit (325°F above ambient)
172:08	--	Gas off; test terminated

Table 1 – Test Observations

Vertical Deflection – The longitudinal centerline vertical deflections of the voided concrete slab assembly measured during the test are shown in Figure 4 and Table 2.

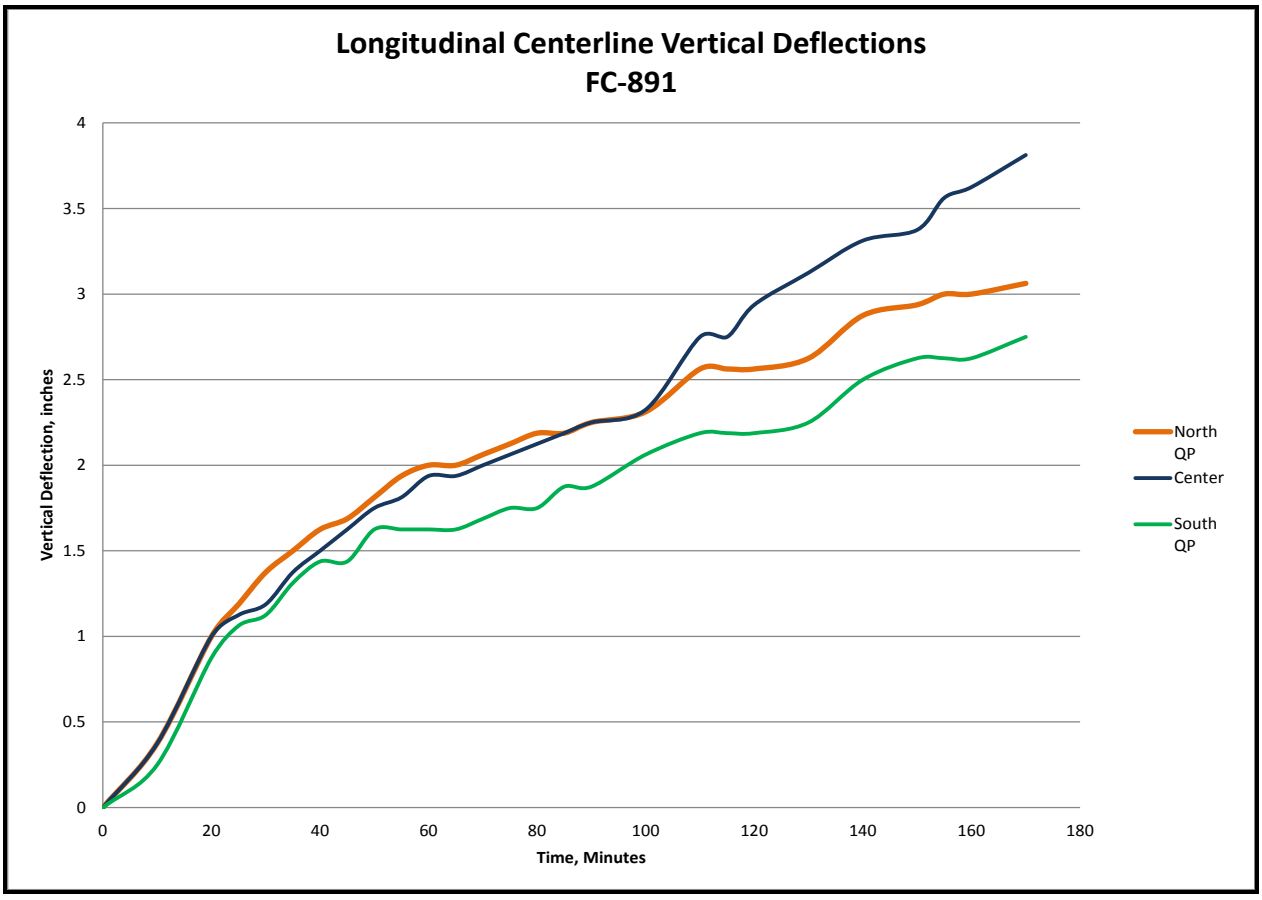

Figure 4 – Longitudinal Centerline Vertical Deflections of Unexposed Surface

Test Time, Min:Sec	Vertical Deflection of Unexposed Surface (in.)		
	North QP	Center	South QP
10:00	3/8	3/8	1/4
20:00	1	1	7/8
25:00	1-3/16	1-1/8	1-1/16
30:00	1-3/8	1-3/16	1-1/8
35:00	1-1/2	1-3/8	1-5/16
40:00	1-5/8	1-1/2	1-7/16
45:00	1-11/16	1-5/8	1-7/16
50:00	1-13/16	1-3/4	1-5/8
55:00	1-15/16	1-13/16	1-5/8
60:00	2	1-7/8	1-5/8
65:00	2	1-7/8	1-5/8
70:00	2-1/16	2	1-11/16
75:00	2-1/8	2-1/16	1-3/4
80:00	2-3/16	2-1/8	1-3/4
85:00	2-3/16	2-3/16	1-7/8
90:00	2-1/4	2-1/4	1-7/8
100:00	2-5/16	2-3/8	2-1/16
110:00	2-9/16	2-3/4	2-3/16
115:00	2-9/16	2-3/4	2-3/16
120:00	2-9/16	2-15/16	2-3/16
130:00	2-5/8	3-1/8	2-1/4
140:00	2-7/8	3-5/16	2-1/2
150:00	2-15/16	3-3/8	2-5/8
155:00	3	3-9/16	2-5/8
160:00	3	3-5/8	2-5/8
170:00	3-1/16	3-13/16	2-3/4

Table 2 – Longitudinal Centerline Vertical Deflections of Unexposed Surface

Conclusion

The following conclusion is based on the results of the fire test presented in this report.

The voided concrete slab assembly constructed of the materials and in the manner described in this report achieved a 2 hr. unrestrained assembly rating when exposed to fire in accordance with Test Method ASTM E119-16a.

The above classification is based on the "*Conditions of Acceptance – Unrestrained Assembly Classification*" for tests of floors and roofs in ASTM E119 – 16a Standard Test Methods for Fire Tests of Building Construction and Materials.

APPENDIX A

Furnace Temperature Data
FC-891

Test Time	FURNACE TEMPERATURES (°F)																
H:MM:SS	FCF01	FCF02	FCF03	FCF04	FCF05	FCF06	FCF07	FCF08	FCF09	FCF10	FCF11	FCF12	FCF13	FCF14	FCF15	FCF16	AVG
0:00:00	75	76	74	76	75	75	75	75	75	75	75	74	76	76	75	76	75
0:01:00	255	229	250	253	168	296	240	311	283	248	269	223	245	233	238	227	248
0:02:00	382	391	451	405	307	437	401	442	450	391	408	372	400	380	392	388	400
0:03:00	614	628	706	625	509	667	664	677	687	618	646	622	646	642	685	647	643
0:04:00	697	788	884	732	613	793	816	745	792	754	780	760	782	780	836	802	772
0:05:00	833	953	1064	882	740	962	979	888	928	907	936	920	945	945	1003	960	928
0:06:00	889	1051	1204	968	834	1069	1097	941	1018	1000	1043	1040	1050	1025	1085	1067	1024
0:07:00	937	1097	1244	1009	863	1126	1130	961	1046	1060	1108	1090	1103	1085	1136	1115	1069
0:08:00	999	1174	1320	1061	937	1220	1216	1042	1102	1129	1186	1191	1171	1130	1208	1196	1143
0:09:00	1006	1232	1375	1117	996	1300	1301	1112	1167	1196	1265	1281	1189	1155	1251	1258	1200
0:10:00	960	1242	1418	1186	1028	1367	1398	1181	1239	1303	1346	1343	1269	1179	1296	1274	1252
0:11:00	952	1246	1435	1227	1043	1394	1449	1213	1280	1353	1373	1360	1306	1203	1318	1276	1277
0:12:00	959	1239	1435	1234	1054	1397	1478	1228	1303	1372	1383	1356	1318	1216	1324	1271	1286
0:13:00	955	1227	1410	1247	1053	1384	1479	1244	1322	1390	1377	1341	1331	1228	1331	1254	1286
0:14:00	983	1258	1434	1259	1086	1424	1486	1254	1315	1380	1393	1371	1350	1229	1329	1295	1303
0:15:00	1008	1295	1463	1274	1111	1451	1482	1263	1314	1383	1402	1377	1350	1239	1356	1315	1318
0:16:00	1022	1313	1504	1295	1124	1462	1496	1273	1318	1399	1414	1389	1387	1263	1348	1326	1333
0:17:00	1028	1328	1504	1302	1136	1488	1509	1285	1300	1394	1431	1434	1415	1274	1353	1354	1346
0:18:00	1024	1313	1497	1311	1134	1466	1525	1294	1328	1427	1437	1448	1419	1289	1356	1334	1350
0:19:00	1059	1358	1539	1336	1176	1504	1520	1304	1333	1423	1439	1457	1424	1291	1370	1372	1369
0:20:00	1094	1402	1586	1357	1208	1526	1528	1319	1344	1429	1468	1481	1450	1325	1386	1391	1393
0:21:00	1115	1423	1611	1365	1232	1545	1537	1325	1351	1452	1476	1481	1464	1345	1412	1404	1409
0:22:00	1125	1452	1602	1366	1238	1559	1553	1338	1362	1469	1498	1503	1498	1356	1420	1415	1422
0:23:00	1115	1450	1575	1356	1238	1574	1575	1360	1348	1485	1520	1517	1502	1367	1429	1404	1426
0:24:00	1147	1454	1591	1358	1257	1579	1570	1369	1351	1501	1512	1530	1511	1392	1431	1403	1435
0:25:00	1247	1519	1611	1356	1253	1571	1576	1368	1342	1520	1523	1512	1533	1413	1440	1412	1450
0:26:00	1270	1558	1640	1363	1257	1590	1591	1385	1350	1537	1538	1529	1553	1424	1460	1425	1467
0:27:00	1289	1560	1647	1363	1272	1591	1592	1382	1352	1549	1545	1540	1581	1449	1471	1429	1476
0:28:00	1271	1567	1645	1364	1265	1595	1596	1376	1343	1553	1552	1536	1575	1443	1481	1425	1474
0:29:00	1292	1576	1656	1381	1281	1599	1593	1390	1346	1562	1548	1519	1566	1438	1489	1432	1479
0:30:00	1359	1579	1639	1394	1342	1620	1618	1420	1374	1558	1555	1520	1545	1441	1495	1438	1494
0:31:00	1368	1575	1622	1400	1364	1631	1634	1434	1425	1564	1554	1521	1565	1459	1501	1432	1503
0:32:00	1381	1577	1620	1430	1376	1636	1631	1437	1416	1578	1550	1509	1570	1466	1512	1436	1508
0:33:00	1370	1585	1620	1417	1382	1636	1634	1421	1391	1581	1555	1510	1553	1472	1521	1446	1506
0:34:00	1371	1573	1599	1386	1386	1624	1638	1403	1392	1580	1559	1515	1562	1490	1537	1460	1505
0:35:00	1365	1573	1606	1422	1369	1637	1638	1426	1389	1594	1588	1555	1615	1523	1551	1486	1521
0:36:00	1376	1580	1622	1414	1378	1647	1639	1430	1400	1625	1594	1573	1639	1547	1567	1492	1533
0:37:00	1361	1579	1629	1418	1381	1653	1640	1432	1410	1634	1589	1585	1646	1546	1571	1497	1536
0:38:00	1362	1570	1621	1414	1382	1643	1626	1425	1402	1626	1585	1578	1649	1550	1576	1499	1532
0:39:00	1338	1553	1608	1413	1382	1640	1627	1425	1404	1620	1590	1574	1652	1547	1573	1499	1528
0:40:00	1371	1575	1634	1442	1411	1667	1654	1460	1430	1651	1606	1607	1664	1558	1584	1520	1552
0:41:00	1393	1594	1648	1466	1429	1677	1665	1479	1446	1663	1618	1615	1673	1571	1589	1524	1566
0:42:00	1395	1594	1659	1469	1433	1680	1669	1478	1440	1652	1628	1627	1675	1578	1605	1536	1570
0:43:00	1402	1586	1642	1464	1430	1672	1663	1472	1432	1650	1622	1615	1677	1582	1619	1539	1567
0:44:01	1392	1578	1636	1455	1426	1666	1654	1462	1424	1637	1617	1605	1681	1587	1622	1543	1562
0:45:00	1405	1592	1653	1473	1447	1685	1668	1480	1446	1665	1632	1622	1684	1598	1626	1548	1577
0:46:00	1427	1604	1664	1479	1456	1695	1679	1488	1454	1682	1646	1635	1702	1616	1639	1565	1589
0:47:00	1435	1609	1665	1486	1467	1700	1686	1502	1463	1693	1653	1647	1714	1626	1648	1577	1598
0:48:00	1435	1605	1658	1488	1468	1695	1688	1500	1465	1685	1657	1652	1716	1628	1645	1573	1597
0:49:00	1434	1600	1656	1483	1469	1689	1679	1493	1460	1677	1643	1641	1706	1621	1645	1575	1592
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0:51:00	1467	1624	1672	1504	1498	1716	1705	1530	1490	1718	1673	1666	1732	1649	1666	1593	1619
0:52:00	1474	1631	1680	1522	1507	1719	1715	1540	1498	1723	1685	1681	1735	1654	1662	1595	1626
0:53:00	1482	1630	1679	1518	1508	1719	1711	1535	1492	1714	1681	1678	1734	1657	1680	1610	1627
0:54:00	1478	1629	1673	1513	1508	1717	1712	1538	1492	1716	1681	1680	1740	1658	1680	1607	1626
0:55:00	1469	1618	1672	1508	1508	1713	1704	1532	1492	1706	1669	1658	1725	1653	1678	1604	1619
0:56:00	1496	1638	1691	1533	1525	1732	1726	1558	1508	1733	1693	1685	1746	1675	1692	1620	1641
0:57:00	1510	1645	1696	1549	1533	1738	1736	1564	1511	1735	1696	1691	1753	1684	1702	1630	1648
0:58:00	1519	1648	1696	1553	1544	1742	1737	1577	1518	1737	1693	1686	1751	1681	1700	1622	1650
0:59:00	1513	1642	1693	1541	1537	1734	1730	1567	1515	1731	1697	1688	1758	1685	1706	1626	1648
1:00:00	1501	1627	1675	1527	1529	1718	1712	1549	1503	1714	1686	1677	1749	1687	1724	1640	1639

Test Time	FURNACE TEMPERATURES (°F)																
H:MM:SS	FCF01	FCF02	FCF03	FCF04	FCF05	FCF06	FCF07	FCF08	FCF09	FCF10	FCF11	FCF12	FCF13	FCF14	FCF15	FCF16	AVG
1:01:00	1526	1651	1700	1559	1552	1747	1744	1583	1527	1743	1715	1713	1760	1695	1719	1651	1662
1:02:00	1535	1655	1706	1562	1557	1746	1746	1595	1534	1751	1714	1715	1768	1706	1726	1652	1667
1:03:00	1538	1658	1707	1566	1566	1751	1751	1595	1541	1758	1715	1719	1766	1704	1725	1653	1670
1:04:00	1533	1655	1705	1562	1559	1745	1743	1589	1535	1744	1713	1708	1766	1705	1727	1652	1665
1:05:00	1521	1643	1695	1554	1553	1736	1731	1580	1530	1732	1708	1696	1767	1705	1733	1653	1659
1:06:00	1544	1657	1706	1573	1571	1751	1749	1602	1548	1756	1719	1723	1770	1714	1728	1661	1673
1:07:00	1559	1671	1721	1588	1584	1768	1763	1603	1556	1769	1735	1719	1781	1727	1744	1671	1685
1:08:00	1566	1673	1726	1595	1588	1765	1761	1610	1560	1765	1733	1715	1780	1729	1746	1672	1686
1:09:00	1571	1677	1726	1601	1596	1765	1770	1622	1576	1771	1733	1724	1777	1723	1732	1662	1689
1:10:00	1561	1665	1714	1590	1585	1749	1750	1601	1556	1746	1718	1702	1773	1723	1745	1666	1678
1:11:00	1566	1667	1716	1588	1590	1759	1755	1609	1564	1769	1727	1702	1785	1736	1749	1668	1684
1:12:00	1580	1681	1730	1606	1603	1771	1774	1624	1577	1778	1736	1717	1791	1743	1761	1679	1697
1:13:00	1591	1686	1734	1611	1610	1771	1774	1627	1580	1784	1735	1719	1795	1748	1755	1675	1700
1:14:00	1595	1689	1739	1619	1616	1776	1783	1636	1589	1772	1741	1735	1789	1744	1752	1681	1704
1:15:00	1589	1683	1734	1614	1610	1766	1773	1625	1583	1769	1733	1719	1796	1748	1758	1679	1699
1:16:00	1578	1669	1719	1610	1603	1751	1763	1616	1586	1746	1723	1711	1778	1736	1750	1677	1689
1:17:00	1605	1695	1742	1630	1627	1781	1795	1651	1604	1776	1753	1741	1794	1752	1759	1685	1712
1:18:00	1621	1704	1754	1635	1636	1790	1796	1657	1606	1799	1762	1744	1801	1764	1766	1691	1720
1:19:00	1628	1713	1759	1650	1652	1811	1811	1672	1616	1813	1773	1754	1818	1772	1780	1710	1733
1:20:00	1640	1725	1768	1661	1660	1821	1817	1688	1620	1821	1784	1775	1834	1784	1787	1721	1744
1:21:00	1628	1720	1765	1663	1660	1816	1809	1676	1623	1807	1777	1764	1833	1779	1793	1726	1740
1:22:00	1640	1728	1770	1669	1670	1832	1825	1696	1640	1827	1795	1780	1845	1792	1795	1732	1752
1:23:00	1671	1751	1787	1690	1697	1845	1832	1704	1652	1841	1806	1801	1848	1800	1802	1743	1767
1:24:00	1675	1763	1791	1705	1706	1840	1829	1721	1661	1835	1817	1824	1855	1804	1808	1762	1775
1:25:00	1697	1771	1795	1708	1712	1831	1824	1725	1667	1827	1810	1827	1846	1797	1803	1767	1775
1:26:00	1685	1767	1798	1711	1712	1839	1830	1726	1662	1833	1811	1807	1851	1800	1804	1751	1774
1:27:00	1689	1769	1798	1711	1710	1843	1833	1721	1663	1840	1816	1804	1857	1805	1812	1755	1777
1:28:00	1719	1786	1809	1732	1726	1839	1832	1733	1682	1836	1819	1842	1850	1808	1814	1787	1788
1:29:00	1735	1798	1813	1734	1730	1839	1829	1737	1680	1838	1822	1843	1849	1809	1820	1785	1791
1:30:00	1745	1804	1814	1733	1733	1834	1827	1733	1687	1833	1821	1844	1843	1805	1818	1788	1791
1:31:00	1737	1804	1818	1738	1738	1839	1830	1738	1686	1834	1820	1838	1851	1808	1820	1780	1792
1:32:00	1725	1799	1818	1737	1738	1848	1838	1742	1682	1841	1823	1828	1858	1811	1816	1774	1792
1:33:00	1759	1817	1827	1752	1745	1841	1831	1745	1702	1838	1823	1851	1842	1813	1825	1800	1801
1:34:00	1767	1822	1829	1758	1748	1843	1834	1747	1699	1840	1830	1857	1844	1815	1827	1809	1804
1:35:00	1772	1827	1832	1761	1751	1845	1836	1750	1706	1844	1833	1859	1848	1817	1829	1806	1807
1:36:00	1770	1827	1832	1760	1757	1850	1842	1751	1705	1849	1835	1858	1852	1819	1832	1803	1809
1:37:00	1755	1818	1834	1758	1758	1856	1852	1758	1698	1849	1835	1847	1868	1823	1833	1795	1808
1:38:00	1774	1829	1837	1770	1764	1854	1846	1756	1716	1851	1836	1863	1855	1826	1835	1811	1814
1:39:00	1788	1838	1843	1775	1767	1857	1845	1764	1718	1858	1832	1868	1853	1829	1842	1820	1819
1:40:00	1790	1845	1848	1780	1772	1859	1846	1770	1726	1858	1834	1869	1858	1833	1843	1820	1822
1:41:00	1792	1844	1848	1780	1773	1858	1849	1767	1721	1858	1841	1870	1861	1834	1843	1823	1823
1:42:00	1795	1847	1851	1781	1779	1863	1853	1763	1723	1860	1844	1869	1861	1834	1842	1821	1824
1:43:00	1779	1839	1852	1785	1777	1869	1858	1767	1723	1864	1847	1860	1871	1833	1845	1814	1824
1:44:00	1798	1851	1855	1790	1780	1862	1854	1776	1733	1863	1846	1874	1866	1838	1850	1837	1829
1:45:00	1804	1852	1857	1792	1786	1865	1852	1771	1737	1862	1846	1874	1862	1839	1855	1840	1831
1:46:00	1802	1851	1857	1792	1783	1861	1854	1779	1736	1861	1846	1872	1856	1836	1849	1834	1829
1:47:00	1808	1853	1857	1802	1788	1865	1856	1789	1735	1864	1845	1872	1860	1839	1850	1835	1832
1:48:00	1807	1856	1860	1795	1794	1870	1865	1779	1737	1869	1854	1877	1874	1845	1854	1833	1836
1:49:00	1808	1856	1864	1802	1791	1866	1857	1782	1744	1866	1850	1874	1863	1845	1858	1842	1836
1:50:00	1810	1856	1861	1803	1793	1867	1852	1789	1749	1863	1848	1875	1859	1843	1856	1844	1835
1:51:00	1810	1857	1861	1811	1794	1867	1852	1796	1747	1865	1849	1876	1860	1845	1857	1843	1837
1:52:00	1818	1860	1863	1811	1799	1871	1859	1798	1750	1872	1853	1882	1869	1850	1859	1848	1841
1:53:00	1823	1864	1868	1811	1805	1877	1868	1783	1748	1878	1859	1878	1878	1852	1865	1843	1844
1:54:00	1821	1865	1872	1816	1807	1878	1868	1790	1759	1875	1859	1877	1874	1853	1864	1845	1845
1:55:00	1821	1863	1868	1819	1806	1876	1861	1808	1762	1871	1857	1881	1866	1854	1865	1850	1845
1:56:00	1825	1863	1870	1822	1808	1876	1862	1803	1764	1872	1858	1885	1869	1857	1868	1856	1847
1:57:00	1827	1866	1874	1823	1811	1877	1864	1807	1760	1878	1859	1888	1875	1861	1870	1854	1850
1:58:00	1833	1870	1875	1824	1818	1883	1872	1797	1759	1884	1868	1889	1884	1862	1874	1853	1853
1:59:00	1838	1876	1881	1824	1822	1888	1879	1803	1764	1891	1867	1890	1897	1866	1875	1853	1857
2:00:00	1834	1873	1877	1831	1820	1884	1870	1819	1772	1883	1866	1890	1881	1869	1876	1862	1857

Test Time	FURNACE TEMPERATURES (°F)																
H:MM:SS	FCF01	FCF02	FCF03	FCF04	FCF05	FCF06	FCF07	FCF08	FCF09	FCF10	FCF11	FCF12	FCF13	FCF14	FCF15	FCF16	AVG
2:01:00	1837	1873	1877	1832	1823	1884	1869	1819	1774	1885	1868	1893	1882	1872	1877	1863	1858
2:02:00	1839	1876	1881	1837	1824	1886	1872	1817	1777	1887	1868	1895	1884	1874	1881	1869	1860
2:03:00	1844	1879	1885	1837	1830	1889	1881	1811	1780	1895	1874	1899	1892	1877	1883	1867	1864
2:04:00	1849	1884	1890	1840	1835	1894	1885	1808	1781	1898	1871	1896	1897	1879	1883	1863	1866
2:05:00	1850	1885	1889	1841	1835	1892	1884	1822	1788	1898	1879	1903	1892	1880	1887	1872	1869
2:06:00	1851	1881	1889	1846	1834	1892	1880	1829	1785	1898	1880	1903	1893	1882	1888	1874	1869
2:07:00	1852	1885	1891	1848	1838	1893	1881	1826	1791	1899	1878	1904	1894	1884	1890	1879	1871
2:08:00	1856	1888	1894	1849	1841	1896	1886	1825	1793	1904	1882	1906	1897	1887	1891	1877	1873
2:09:00	1860	1893	1899	1847	1846	1903	1894	1825	1789	1910	1887	1909	1906	1889	1894	1873	1877
2:10:00	1863	1895	1899	1848	1850	1906	1899	1827	1795	1908	1892	1913	1907	1891	1898	1877	1879
2:11:00	1863	1895	1900	1855	1849	1902	1893	1838	1803	1910	1894	1914	1905	1895	1899	1886	1881
2:12:00	1866	1895	1902	1858	1850	1903	1892	1843	1803	1909	1891	1913	1908	1897	1900	1888	1882
2:13:00	1868	1895	1905	1861	1852	1904	1894	1847	1804	1911	1894	1919	1910	1900	1901	1890	1885
2:14:00	1872	1901	1907	1863	1857	1908	1899	1841	1807	1915	1894	1919	1913	1900	1903	1888	1887
2:15:00	1873	1903	1908	1862	1861	1913	1909	1839	1806	1920	1900	1921	1919	1903	1906	1883	1889
2:16:00	1875	1903	1911	1865	1860	1910	1904	1845	1814	1918	1900	1923	1915	1906	1909	1893	1891
2:17:00	1876	1904	1911	1870	1860	1910	1900	1856	1816	1915	1900	1922	1915	1907	1907	1893	1891
2:18:00	1878	1901	1914	1872	1861	1909	1904	1849	1814	1918	1901	1922	1918	1910	1909	1899	1892
2:19:00	1881	1907	1914	1871	1866	1913	1906	1849	1819	1923	1903	1926	1918	1910	1912	1900	1895
2:20:00	1886	1910	1914	1875	1870	1920	1910	1860	1820	1926	1904	1929	1923	1913	1915	1899	1898
2:21:00	1886	1912	1920	1876	1871	1923	1915	1851	1822	1928	1905	1930	1927	1915	1917	1899	1900
2:22:00	1886	1913	1921	1878	1871	1919	1909	1857	1826	1927	1907	1931	1926	1917	1917	1907	1901
2:23:00	1889	1913	1922	1881	1872	1921	1911	1861	1825	1928	1909	1932	1928	1922	1919	1911	1903
2:24:00	1890	1916	1926	1886	1876	1927	1926	1866	1833	1930	1923	1942	1932	1918	1922	1910	1908
2:25:00	1888	1932	1947	1901	1880	1937	1947	1883	1830	1931	1933	1933	1925	1912	1927	1905	1913
2:26:00	1875	1940	1949	1903	1887	1958	1967	1894	1840	1960	1949	1945	1961	1927	1946	1919	1926
2:27:00	1893	1949	1957	1910	1896	1956	1969	1899	1845	1958	1951	1950	1964	1935	1951	1931	1932
2:28:00	1894	1954	1964	1912	1897	1961	1970	1903	1850	1962	1954	1953	1968	1941	1956	1933	1936
2:29:00	1906	1958	1971	1911	1900	1964	1973	1906	1849	1963	1956	1954	1967	1943	1957	1936	1938
2:30:00	1907	1960	1971	1920	1905	1968	1978	1908	1849	1971	1959	1958	1976	1948	1961	1940	1943
2:31:00	1895	1958	1970	1922	1904	1975	1985	1910	1853	1976	1964	1959	1979	1948	1960	1934	1943
2:32:00	1908	1960	1973	1925	1910	1974	1985	1916	1855	1974	1967	1963	1975	1945	1964	1940	1946
2:33:00	1918	1968	1975	1931	1914	1974	1986	1918	1861	1973	1969	1967	1979	1954	1966	1946	1950
2:34:00	1925	1970	1977	1934	1917	1976	1988	1922	1867	1973	1971	1969	1978	1953	1967	1948	1952
2:35:00	1928	1972	1978	1935	1919	1980	1992	1924	1870	1974	1974	1971	1976	1954	1969	1949	1954
2:36:00	1922	1974	1985	1936	1922	1985	1997	1927	1863	1984	1977	1972	1986	1960	1970	1946	1957
2:37:00	1912	1973	1989	1944	1921	1990	2000	1928	1867	1990	1980	1975	1989	1962	1974	1949	1959
2:38:00	1931	1979	1991	1942	1927	1987	1998	1931	1872	1986	1980	1978	1988	1970	1975	1957	1962
2:39:00	1936	1982	1992	1946	1930	1989	1999	1935	1875	1986	1983	1980	1987	1965	1981	1961	1964
2:40:00	1939	1983	1991	1948	1931	1988	2000	1937	1879	1984	1983	1983	1989	1969	1982	1966	1966
2:41:00	1939	1985	1995	1952	1933	1992	2004	1937	1877	1988	1986	1984	1991	1969	1982	1966	1967
2:42:00	1933	1985	1996	1949	1933	1992	2003	1938	1874	1993	1984	1984	1991	1968	1981	1962	1967
2:43:00	1932	1982	1999	1948	1932	1987	1996	1936	1883	1987	1982	1981	1989	1970	1983	1966	1966
2:44:00	1936	1981	1993	1946	1931	1985	1995	1936	1885	1982	1981	1981	1984	1969	1983	1969	1965
2:45:00	1939	1982	1994	1951	1934	1984	1997	1937	1887	1982	1983	1983	1986	1973	1986	1975	1967
2:46:00	1939	1984	1995	1954	1935	1987	2000	1939	1890	1983	1986	1984	1985	1972	1987	1974	1968
2:47:00	1936	1986	1996	1960	1936	1994	2005	1943	1882	1995	1987	1987	1998	1976	1988	1973	1971
2:48:00	1941	1983	2000	1951	1935	1984	1997	1940	1881	1985	1981	1980	1991	1973	1986	1972	1968
2:49:00	1934	1977	1994	1950	1931	1978	1989	1934	1887	1974	1977	1974	1980	1972	1982	1969	1963
2:50:00	1933	1976	1996	1949	1930	1976	1988	1934	1889	1974	1976	1971	1981	1976	1979	1969	1962
2:51:00	1935	1976	1992	1949	1932	1977	1989	1936	1889	1978	1977	1973	1983	1973	1979	1971	1963
2:52:00	1941	1979	1993	1955	1935	1980	1992	1938	1890	1980	1979	1975	1986	1971	1981	1972	1965

APPENDIX B

Unexposed Surface Temperature Data
FC-891

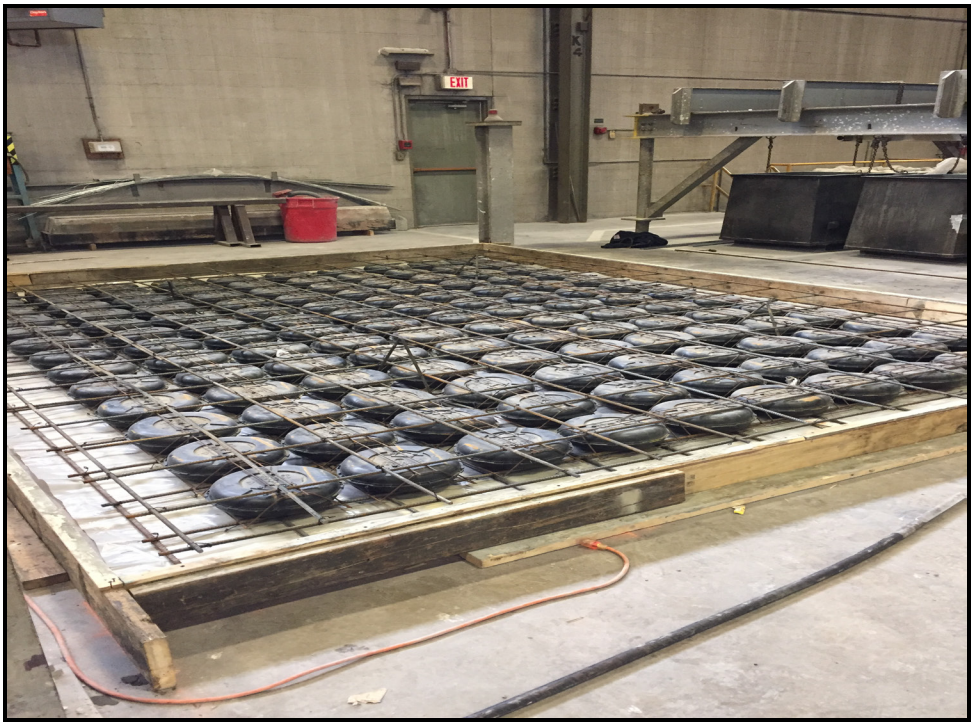
Test Time	UNEXPOSED SURFACE TEMPERATURES (°F)										
H:MM:SS	TC1	TC2	TC3	TC4	TC5	TC6	TC7	TC8	TC9	AVG	MAX
0:00:00	76	73	74	76	75	74	75	73	74	74	76
0:01:00	76	73	74	76	75	74	75	72	74	74	76
0:02:00	76	73	74	76	75	74	75	72	74	74	76
0:03:00	76	73	74	76	75	74	75	72	74	74	76
0:04:00	76	73	74	76	75	74	75	72	74	74	76
0:05:00	76	73	74	75	75	74	75	72	74	74	76
0:06:00	76	73	74	75	74	74	75	72	74	74	76
0:07:00	76	73	74	75	74	74	75	73	74	74	76
0:08:00	76	72	74	75	74	74	75	72	74	74	76
0:09:00	76	72	73	75	74	74	75	73	74	74	76
0:10:00	76	72	74	75	74	74	75	73	74	74	76
0:11:00	76	72	73	75	74	74	75	74	74	74	76
0:12:00	76	72	74	75	74	74	75	74	74	74	76
0:13:00	76	72	74	75	74	74	76	75	74	74	76
0:14:00	76	72	74	75	74	74	76	75	74	74	76
0:15:00	76	72	74	74	74	74	76	75	74	74	76
0:16:00	76	72	74	75	74	74	76	75	75	74	76
0:17:00	76	72	74	75	74	74	77	75	75	75	77
0:18:00	76	72	74	75	74	75	78	75	75	75	78
0:19:00	76	72	74	75	74	76	78	74	76	75	78
0:20:00	76	72	74	76	74	76	79	75	76	75	79
0:21:00	76	72	74	76	74	76	80	75	77	76	80
0:22:00	75	73	75	77	74	77	80	75	77	76	80
0:23:00	74	73	75	78	74	78	81	75	78	76	81
0:24:00	74	74	75	82	74	78	82	74	78	77	82
0:25:00	75	74	76	84	74	79	83	75	79	77	84
0:26:00	75	75	76	84	74	80	84	75	80	78	84
0:27:00	76	76	77	85	74	80	86	75	81	79	86
0:28:00	77	76	77	86	74	81	87	75	82	79	87
0:29:00	77	77	78	86	74	82	88	76	82	80	88
0:30:00	78	78	79	87	74	84	90	76	83	81	90
0:31:00	79	77	79	87	75	84	91	76	85	82	91
0:32:00	80	78	81	87	75	86	93	76	86	82	93
0:33:00	82	79	82	88	75	87	94	77	87	83	94
0:34:00	83	79	83	89	75	88	96	77	89	84	96
0:35:00	85	80	84	89	76	89	98	77	90	85	98
0:36:00	86	81	85	90	76	89	100	77	92	86	100
0:37:00	88	82	86	91	76	91	102	78	94	88	102
0:38:00	90	83	87	92	77	92	104	78	95	89	104
0:39:00	93	84	89	93	77	93	106	79	97	90	106
0:40:00	97	85	89	94	77	94	108	79	99	91	108
0:41:00	102	86	92	95	78	95	110	79	101	93	110
0:42:00	106	87	92	94	78	95	113	80	103	94	113
0:43:00	114	88	94	94	79	96	116	80	105	96	116
0:44:01	118	89	96	95	79	97	118	81	107	98	118
0:45:00	121	90	96	96	80	98	121	82	109	99	121

Test Time	UNEXPOSED SURFACE TEMPERATURES (°F)										
H:MM:SS	TC1	TC2	TC3	TC4	TC5	TC6	TC7	TC8	TC9	AVG	MAX
0:46:00	122	91	99	99	81	99	124	83	111	101	124
0:47:00	125	92	102	100	82	100	127	83	114	103	127
0:48:00	128	93	104	101	83	101	128	84	116	104	128
0:49:00	130	95	106	102	84	102	130	85	118	106	130
0:50:00	134	96	108	103	85	103	134	86	121	107	134
0:51:00	136	97	108	104	86	103	139	87	123	109	139
0:52:00	138	98	111	105	87	104	143	87	125	111	143
0:53:00	141	99	112	106	88	105	144	88	128	112	144
0:54:00	143	100	114	108	90	106	146	89	130	114	146
0:55:00	144	101	119	109	91	106	151	90	132	116	151
0:56:00	146	102	121	110	92	107	156	91	135	118	156
0:57:00	147	103	122	112	93	108	160	92	137	120	160
0:58:00	149	104	122	113	94	109	165	93	140	121	165
0:59:00	150	106	133	114	96	109	168	94	143	124	168
1:00:00	151	107	130	115	97	110	172	95	145	125	172
1:01:00	153	108	146	117	98	111	175	96	147	128	175
1:02:00	154	109	157	118	99	112	178	97	149	130	178
1:03:00	155	110	174	120	100	113	179	98	151	133	179
1:04:00	156	110	178	121	102	114	181	99	152	135	181
1:05:00	157	111	182	122	103	114	182	100	154	136	182
1:06:00	158	112	185	123	104	115	184	103	157	138	185
1:07:00	159	113	184	124	106	116	187	104	159	139	187
1:08:00	160	113	195	124	107	116	186	105	161	141	195
1:09:00	161	114	198	126	108	117	185	107	163	142	198
1:10:00	162	115	189	127	109	118	188	107	166	142	189
1:11:00	163	116	208	129	111	119	190	109	167	146	208
1:12:00	163	116	208	130	112	119	191	111	169	147	208
1:13:00	164	117	209	131	113	120	192	112	171	148	209
1:14:00	164	117	209	132	114	121	193	113	172	148	209
1:15:00	165	118	209	133	115	121	193	115	175	149	209
1:16:00	165	119	209	134	117	122	194	116	177	150	209
1:17:00	166	119	208	136	118	123	195	118	179	151	208
1:18:00	166	120	207	136	119	124	197	119	181	152	207
1:19:00	167	120	208	137	120	125	199	121	184	153	208
1:20:00	167	121	209	137	122	125	207	122	186	155	209
1:21:00	168	122	209	138	123	126	210	123	189	156	210
1:22:00	168	123	210	140	124	127	210	125	193	158	210
1:23:00	169	123	210	140	125	127	212	126	197	159	212
1:24:00	169	124	210	140	127	128	217	128	200	160	217
1:25:00	169	125	209	141	128	129	219	129	201	161	219
1:26:00	170	126	210	142	129	130	221	131	204	162	221
1:27:00	170	126	209	143	130	131	222	132	206	163	222
1:28:00	171	127	210	143	132	131	224	133	208	164	224
1:29:00	171	128	210	143	133	132	225	134	209	165	225
1:30:00	172	129	210	143	134	133	225	136	211	166	225

Test Time	UNEXPOSED SURFACE TEMPERATURES (°F)										
H:MM:SS	TC1	TC2	TC3	TC4	TC5	TC6	TC7	TC8	TC9	AVG	MAX
1:31:00	172	129	210	144	135	134	226	137	213	167	226
1:32:00	173	130	210	144	136	134	228	139	214	168	228
1:33:00	174	131	211	145	138	135	229	140	215	169	229
1:34:00	175	131	210	145	139	136	230	142	217	170	230
1:35:00	176	132	211	146	140	137	230	142	219	170	230
1:36:00	176	133	210	148	141	138	231	144	221	171	231
1:37:00	178	134	210	148	143	138	232	145	222	172	232
1:38:00	178	134	210	149	144	139	233	146	223	173	233
1:39:00	178	135	210	149	145	140	234	147	224	174	234
1:40:00	179	136	210	150	146	141	235	149	226	174	235
1:41:00	179	136	210	150	147	142	236	150	227	175	236
1:42:00	180	137	210	151	149	142	236	151	228	176	236
1:43:00	180	138	210	152	150	143	237	152	229	177	237
1:44:00	181	138	210	153	151	143	238	154	230	178	238
1:45:00	182	139	210	154	152	144	239	154	231	178	239
1:46:00	182	139	210	155	153	145	240	155	232	179	240
1:47:00	182	140	210	155	155	146	240	156	233	180	240
1:48:00	181	141	210	156	156	147	241	157	234	180	241
1:49:00	181	141	211	157	157	147	242	158	235	181	242
1:50:00	181	141	210	158	158	148	243	158	236	182	243
1:51:00	182	142	210	159	159	149	244	159	237	182	244
1:52:00	181	143	210	160	160	150	244	160	238	183	244
1:53:00	183	143	210	160	161	151	245	160	239	184	245
1:54:00	183	144	210	161	162	152	246	161	240	184	246
1:55:00	184	144	209	162	163	152	247	161	241	185	247
1:56:00	184	145	209	162	164	153	248	161	242	185	248
1:57:00	185	145	209	163	165	154	249	161	243	186	249
1:58:00	185	146	209	164	166	155	250	162	244	187	250
1:59:00	185	147	209	164	167	155	251	163	245	187	251
2:00:00	185	147	210	165	168	156	252	164	246	188	252
2:01:00	185	148	210	165	169	157	253	164	247	189	253
2:02:00	186	148	210	166	170	158	254	164	248	189	254
2:03:00	186	149	210	166	171	158	256	164	250	190	256
2:04:00	187	149	210	167	172	159	257	165	251	191	257
2:05:00	187	150	210	169	173	160	259	165	252	192	259
2:06:00	187	151	210	168	174	161	260	166	253	192	260
2:07:00	187	151	210	169	175	161	261	166	254	193	261
2:08:00	188	152	210	169	176	162	263	166	256	194	263
2:09:00	188	153	210	170	177	163	265	167	258	194	265
2:10:00	188	153	210	171	178	164	267	167	259	195	267
2:11:00	189	153	210	171	178	165	270	167	261	196	270
2:12:00	188	154	210	172	179	165	272	167	263	197	272
2:13:00	188	154	210	173	180	166	275	168	265	198	275
2:14:00	189	155	210	174	181	167	277	169	267	199	277
2:15:00	189	155	210	175	182	168	280	168	269	200	280

Test Time	UNEXPOSED SURFACE TEMPERATURES (°F)										
H:MM:SS	TC1	TC2	TC3	TC4	TC5	TC6	TC7	TC8	TC9	AVG	MAX
2:16:00	189	156	210	175	183	168	283	170	271	201	283
2:17:00	189	156	210	176	183	169	285	169	274	201	285
2:18:00	188	157	210	177	184	170	289	170	276	202	289
2:19:00	188	158	210	178	185	170	291	171	279	203	291
2:20:00	189	158	210	178	186	171	294	172	281	205	294
2:21:00	189	159	211	179	187	172	297	175	284	206	297
2:22:00	189	159	211	180	188	172	300	181	287	207	300
2:23:00	189	160	211	181	188	172	303	196	290	210	303
2:24:00	189	160	211	182	189	173	307	196	293	211	307
2:25:00	189	161	211	183	190	174	309	200	296	213	309
2:26:00	189	162	211	183	191	174	313	202	299	214	313
2:27:00	189	162	211	184	192	175	316	203	303	215	316
2:28:00	190	163	211	185	192	175	319	206	306	216	319
2:29:00	190	163	211	185	193	176	322	206	309	217	322
2:30:00	190	164	211	186	194	177	325	208	312	219	325
2:31:00	191	165	211	187	195	177	328	206	315	220	328
2:32:00	191	166	211	187	195	178	331	206	319	220	331
2:33:00	191	167	211	188	196	178	335	205	322	221	335
2:34:00	190	167	211	189	197	179	338	205	325	222	338
2:35:00	191	168	211	191	197	179	341	205	328	223	341
2:36:00	191	169	211	192	198	180	344	204	331	225	344
2:37:00	191	169	211	193	199	180	348	206	335	226	348
2:38:00	191	170	211	194	199	181	351	209	338	227	351
2:39:00	191	171	212	195	200	181	354	210	342	228	354
2:40:00	191	172	212	196	201	182	358	208	345	229	358
2:41:00	192	172	212	197	201	182	361	209	348	230	361
2:42:00	193	173	212	198	202	183	364	210	352	232	364
2:43:00	193	174	212	204	202	183	368	211	355	234	368
2:44:00	193	174	212	203	203	184	371	211	359	234	371
2:45:00	193	175	212	204	204	184	375	211	362	235	375
2:46:00	194	176	212	207	204	184	379	211	365	237	379
2:47:00	197	176	212	207	205	185	382	211	369	238	382
2:48:00	202	177	212	206	205	186	386	211	372	240	386
2:49:00	200	178	212	207	205	186	390	211	375	240	390
2:50:00	200	179	212	207	205	187	393	211	379	242	393
2:51:00	198	179	212	207	206	189	397	211	382	242	397
2:52:00	197	180	212	208	206	189	400	211	386	243	400

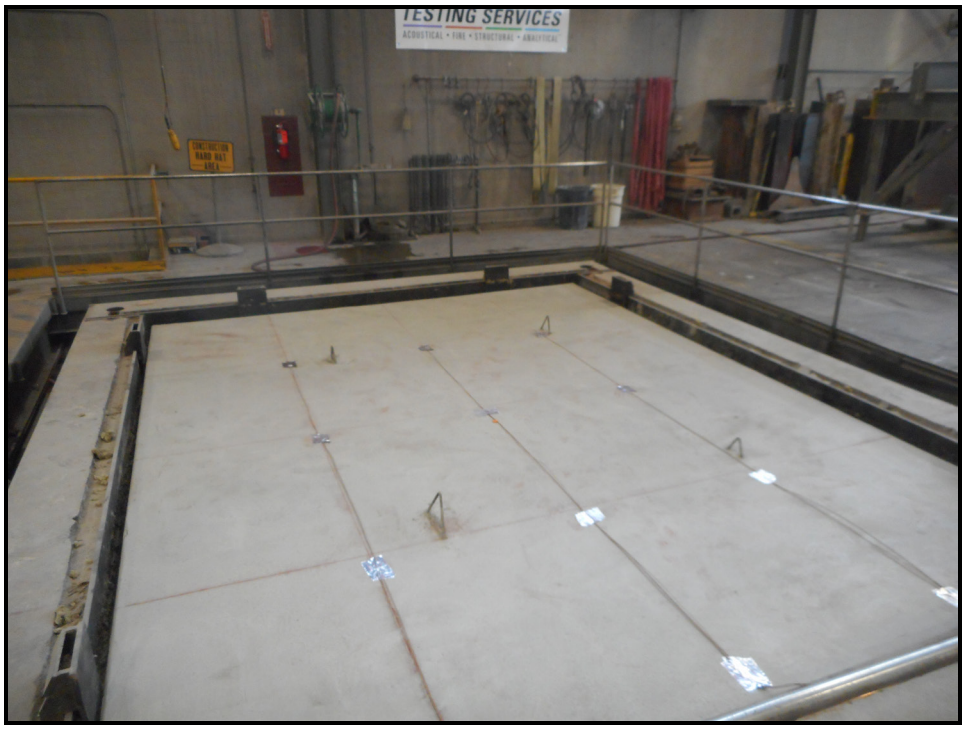
APPENDIX C
Fire Test Photographs
FC-891



Test Specimen Construction – Layout of Plastic Voids and Rebar

Test Specimen Construction – Close-up of Plastic Voids and Rebar Layout

Test Specimen Construction – Pouring Concrete Slab



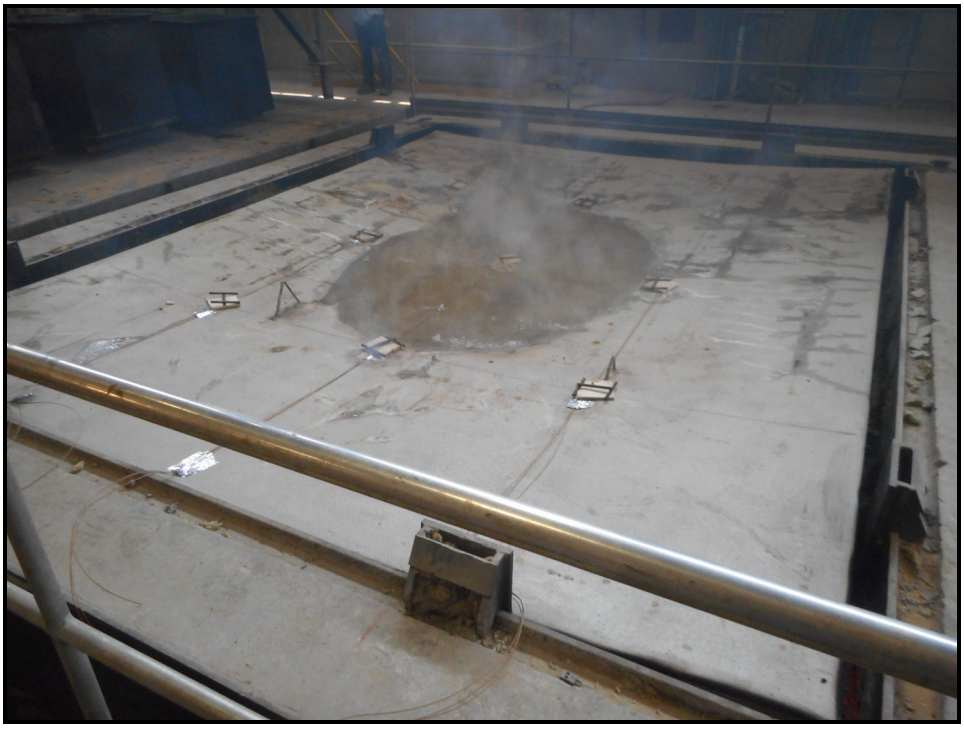
Unexposed Side – Pre-Test (Prior to Loading Tank Placement)

Unexposed Side – Start of Fire Endurance Test

Unexposed Side – Test at 2-Hour Classification Period

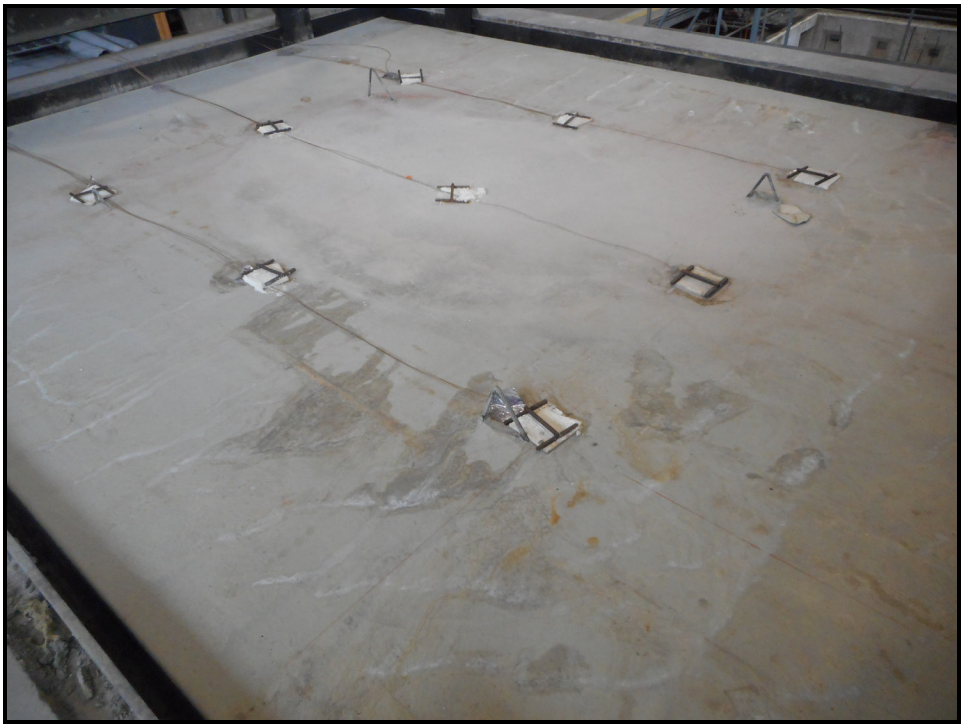
Unexposed Side – Time of Thermal Failure (TC7 Exceeded Temp. Limit)

Unexposed Side – Test Termination



Unexposed Side – Post-Test (Loading Tanks Removed)

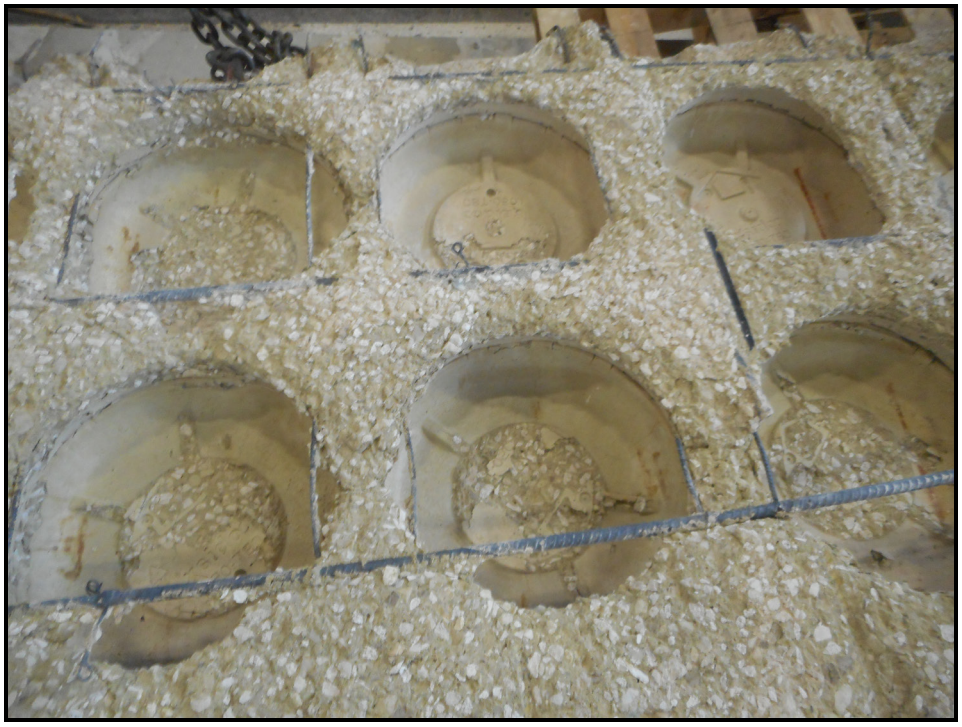
Exposed Side – Post-Test (Removing from Furnace)



Unexposed Side – Post-Test (Slab Cooled for 24 hrs.)

Exposed Side – Post-Test (Slab Cooled for 24 Hrs.)

Slab Cross-Section – Post-Test (Lateral Centerline Cut)



Exposed Side – Post-Test (Close-up of Plastic Void Locations)