Fire Rating Performance of Lightweight CMU Using TXI ES&C

You can be sure that TXI ES&C lightweight aggregate will hold up under extreme fire temperatures and enable the masonry to protect fire fighters, occupants, and property. After all, it has been mined from the earth itself and fired in rotary kilns at temperatures exceeding 2000°F (1000C). There is nothing left to burn in our aggregate – no "loss on ignition" (LOI) that could occur in other types of lightweight aggregates. Recovered from *structural grade* ES&C manufacturing processes, you can feel safe and secure with masonry utilizing TXI ES&C as its primary aggregate constituent.

Fire ratings for masonry, and we might add, the PyroTherm Masonry Wall System, are based on the concrete block's equivalent thickness. This is another way of saying the rating is based on how much solid concrete is in the wall thickness. For example, a hollow two-core concrete block 7.625" (8" nominal) wide that is reported as 53% solid would have an equivalent thickness of 4.04".

Table 1 has examples of typical block sizes needed to meet various fire ratings. Three lightweight and one normal weight (heavyweight) mix designs are shown resulting in four examples of various concrete densities.

Table 1 - Required Wall Thicknesses, in., for Indicated Fire Rating

Fire Rating Period, hrs. :	4.00	3.75	3.50	3.25	3.00	2.75	2.50	2.25	2.00	1.75	1.50	1.25	1.00	0.75
Typical Hollow Units														
Density [b], pcf														
85	12	12	12	12	10	10	8	8	8	8	8	6	4	4
95	14	12	12	12	10	10	10	8	8	8	8	6	4	4
105	14	12	12	12	12	10	10	8	8	8	8	6	4	4
135	16	16	14	14	12	12	10	10	8	8	8	6	4	4
75% Solid Units														
85	8	8	8	8	8	6	6	6	6	6	6	6	4	4
95	8	8	8	8	8	8	6	6	6	6	6	6	4	4
105	8	8	8	8	8	8	6	6	6	6	6	6	4	4
135	10	8	8	8	8	8	8	8	6	6	6	6	4	4
100% Solid Units														
85	6	6	6	6	6	6	6	6	4	4	4	4	4	4
95	6	6	6	6	6	6	6	6	6	4	4	4	4	4
105	6	6	6	6	6	6	6	6	6	4	4	4	4	4
135	8	8	6	6	6	6	6	6	6	4	4	4	4	4

(a) The Fire Resistance Rating Period is calculated using typical concrete equivalency thickness of block as indicated in NCMA TEK 7-1B. The purpose of the above table is to demonstrate the relative performance using different block sizes along with four different concrete densities. Check with TXI or your block producer for help in determining your exact block requirements

(b) The lightweight aggregate used in these calculations is TXI Expanded Shale and Clay (ES&C). The heavyweight aggregate used is calcareous sand. Densities shown are achievable using different ratios of ES&C:Sand. No ES&C aggregate was used in the 135 pcf heavy weight concrete density examples.

(c) All calculations based on specific mix designs and Code Requirements for Determining Fire Resistance of Concrete and Masonry Construction Assemblies, ACI 216.1-07/TMS 216-07. American Concrete Institute and The Masonry Society, 2007. EC&S is from TXI Streetman facility. These are examples only.

Table 2 below shows the typical equivalent thicknesses for most concrete block manufactured in the United States. By using smaller cores or no cores at all, manufacturers can produce units that are 75% solid and solid units respectively.

Table 2, Equivalent Thickness of Concrete Masonry Units, in.

Concrete Masonry Units, nominal size, in.	Actual Unit Thickness, in.	Typical Percent Solid	Equivalent Thickness, in.
4	3.625	73.8%	2.68
6	5.625	55.0%	3.09
8	7.625	53.0%	4.04
10	9.625	46.3%	4.46
12	11.625	44.0%	5.12
14	13.625	40.2%	5.48
16	15.625	38.4%	6.00

Another element of determining the fire rating is the type of aggregate used in the concrete. The 2003 and 2006 International Building Code reference ACI 216.1-07, is herein referred to as the Standard. Table 1 of the Standard lists approved aggregates and the fire ratings as if 100% of the aggregate is used in the mix design. However, since typically more than one type of aggregate is used, the Standard allows linear interpolation based on percentages of the mix design by volume.

The types of aggregates used in the mix design each contribute a certain thickness to achieve a fire rating. For example, suppose you wanted to achieve a two-hour fire ratings using an 8" block. Table 3.1 from ACI 216 indicates a 3.6 inch equivalent thickness is required to achieve a two-hour fire rating using 100% expanded shale aggregate. Table 2 shows that a typical 8" thick block provides 4.04" equivalent thickness so we are more than minimally protected. In fact, the block would have a 2.5 Hour Fire Rating according to Table 1. Since molds can vary, check with your block supplier for the actual equivalency thickness determined by ASTM C 140 laboratory test methods.

ACI 216.1- 97, Table 3.1

Aggregate Type	Minimum required equivalent thickness for fire resistance rating, in.[A,B]				
	1 hr	1.5 hr	2 hr	3 hr	4 hr
Calcareous of Siliceous gravel (other than limestone)	2.8	3.6	4.2	5.3	6.2
Limestone, cinders, air cooled slag	2.7	3.4	4.0	5.0	5.9
Expanded clay, expanded shale or expanded slate	2.6	3.3	3.6	4.4	5.1
Expanded slag or pumice	2.1	2.7	3.2	4.0	4.7
A. Fire resistance ratings between the hourly fire resistance rating periods listed shall be determined by linear interpolation based on the equivalent thickness value of the concrete masonry assembly.					
B. Minimum required equivalent thickness corresponding to the fire resistance rating for units made with a combination of aggregates shall be determined by linear interpolation based on the percent by volume of each aggregate used in the manufacture.					

Blended Aggregates: Units that are manufactured using two or more aggregate types can also be calculated by using the following equation:

$T_r = (T_1 \times V_1) + (T_2 \times V_2)$

where:

T_r = required equivalent thickness for a specific fire resistance rating of an assembly constructed of block with combined aggregates, in.

T_1, T_2 = required equivalent thickness from Table 1 for masonry from Table 1 for each aggregate type

V_1, V_2 = volume in percentage of each material used in the mix design.

Example:

Using a mix design of 60% expanded shale and 40% of calcareous sand by volume:

T_1 for expanded shale (2 hr rating) = 3.6 in.

T_2 for calcareous sand (2 hr rating) = 4.2 in.

T_r = (3.6 x 0.60) + (4.2 x 0.40) = 2.16 + 1.68 = 3.84 in. required

Since an 8" thick unit typically provides 4.04 in. equivalent thickness as shown in Table 2, the unit would meet the required thickness of 3.84 inches shown above.

The use of fire-rated masonry containing all TXI ES&C aggregate (with no sand) as the only aggregate may provide the required protection solution for steel columns, tubing, and pipe. Refer to International Building Code 2006, Section 721 for equivalency thickness required of rated masonry for structural steel element protection. See recently updated NCMA TEK 7-6A, *Steel Column Fire Protection* for more information regarding column protection using low density concrete masonry units.

TXI ES&C is fired and expanded in temperatures exceeding 2000 degrees F. This is the reason masonry using TXI ES&C performs so well in a fire related incident. It has been demonstrated that lightweight concrete masonry using expanded shale or clay in the concrete mix design and subjected to fire incidents will continue to provide structural support during and after the fire due to lower thermal expansion. Other types of concrete masonry do not compare. Underwriters Laboratory 618 has long recognized expanded shale and clay as an acceptable aggregate for fire-rated concrete block. Less portland cement is required than other type of aggregates and still meet the UL fire rating requirements.