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Column Research Council

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Designing Fire Protection for Steel Columns

FIRE-RESISTANCE RATINGS FOR COLUMNS PROTECTED WITH GYPSUM WALLBOARD AND STEEL COVERS

Protective designs for steel columns required by building codes are based on fire tests specified by ASTM E119, "Standard Method of Fire Tests of Building Construction and Materials".

A variety of protective materials have been tested, and the results of hundreds of fire tests of steel columns have been published and made readily obtainable. But most of these fire tests have been conducted on W10x49 steel columns, and there has been no acceptable procedure available for evaluating fire resistance of the full range of steel columns commonly encountered in building construction.

Recently, however, a study completed by American Iron and Steel Institute, has developed a procedure that provides a means of making this evaluation.

American Iron and Steel Institute sponsored fire research of steel columns at both Underwriters' Laboratories, Inc. and the National Research Council of Canada to develop the fundamental data that were used for the above-mentioned procedure.

Twelve columns of different sizes and shapes were tested in accordance with ASTM E119. The various columns were boxed in with one or more layers of gypsum wallboard in order to achieve protection of from one to four hours of fire endurance. Two types of gypsum wallboard were used: type X and regular. There is no significant difference in thermal properties between these types. Inorganic fibers are added to type X gypsum wallboard in order to enhance its structural integrity. To ensure the integrity of the protection throughout the fire period, the assemblies were enclosed in sheet-steel covers.

Most test assemblies were prepared in the following manner: The first layer of gypsum wallboard was boxed around the column and held in place with masking tape. Succeeding layers were applied in a repetition of this procedure. Two sections of sheet-steel covers were then placed in position around the column (Fig. 1). The two vertical joints (Fig. 1, Detail A) were locked in place by hammering with a rubber mallet.

However, in several assemblies, the outer layer of gypsum wallboard was laminated to the steel covers with water-glass adhesive (sodium silicate). Both the inner (unexposed) surface of the cover and the "outer" surface of the

Figure 1. Column protection design: 1) structural steel column, 2) gypsum wallboard in thickness (layers) as needed, and 3) 24 gage (0.024") galvanized (wipe-coat), or stainless sheet-steel cover with snap-lock joint. For one- and two-hour column designs, steel covers may be placed under the outermost wallboard layer.
wallboard were coated with adhesive. No special techniques were used for this procedure. After approximately fifteen minutes, the assembly was placed in position and the column covers were locked in place at the joints as above.

But, no matter what method is used in applying the gypsum wallboard, test results indicate that the steel column covers provide the necessary integrity for the protection.

For practical considerations, it is suggested that sheet-steel covers be kept to a maximum thickness of 0.035 inches; this permits the sheet-steel cover to be fabricated with standard equipment normally available in sheet metal fabricating shops.

**TEST RESULTS**

Fire-test results for various column sizes and shapes are given in Table A. Following the tests, it was observed that the steel-cover joints were unaffected by the fire exposure. Since the steel covers remained in place throughout the test, the gypsum wallboard was kept intact around the column, thereby insuring maximum benefit from the insulation.

Because test furnaces have a highly oxidizing atmosphere, galvanized sheet-steel covers perform satisfactorily for 3 hours. Beyond 3 hours, it may be necessary to use stainless sheet-steel covers. For column ratings of two hours or less, current test data show that the uncoated sheet may be placed under the outer layer of wallboard, and that this layer may be screwed to the sheet-steel in a conventional manner.

**TABLE A FIRE TEST RESULTS**

<table>
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<tr>
<th>TEST NO.</th>
<th>SECTION</th>
<th>D</th>
<th>W/D</th>
<th>h</th>
<th>W/l</th>
<th>W'</th>
<th>W'/D</th>
<th>FE</th>
<th>CALCULATED</th>
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<td>W14x142</td>
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<td>15.62</td>
<td>31.12</td>
<td>1.30</td>
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- **D**: Heated perimeter of steel (backside of protection), inches
- **W**: Weight of steel, lb/ft
- **W/D**: Weight of steel to heated perimeter ratio
- **W'**: Weight of protection, lb/ft
- **W'/: Weight of steel section with protection, lb/ft
- **h**: Thickness of protection, inches
- **W'/D**: Weight of protected steel to heated perimeter ratio
- **FE**: Tested fire endurance, minutes
CONCLUSIONS

Based on the results obtained from this test program, a scaling method for predicting fire-resistance ratings for steel columns protected by gypsum wallboard has been developed. This method takes into account the moisture content of the gypsum wallboard. In the calculations, total weight of both the column and its protection (W') is expressed as follows:

\[ W' = W + \left( \frac{50 \cdot h \cdot D}{144} \right) \]

Where

- \( W \) = weight of steel, lb/ft
- \( h \) = thickness of protection, inches
- \( D \) = heated perimeter of steel column (backside of protection), inches

From this, the following formula for calculating the fire endurance (t) of steel columns protected with gypsum wallboard can be expressed as follows:

\[ t = 130 \left( \frac{h \cdot W' \cdot D}{2} \right)^{0.75} \]
Figure 3. Required thickness of gypsum wallboard for fire-resistance for various sizes and shapes of steel columns.

For steel columns of any size and shape, the gypsum wallboard thickness needed for a specific fire-resistance rating can be quickly established by referring to Figures 2 and 3. These graphs are diagrammatic representations of the formula for “t” given on the preceding page.