URETHANE FOAM INSULATION
OF BRIDGE CONCRETE

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Research Project 69 TI-5
Research Report No. R-729

State of Michigan
Department of State Highways
Lansing, February 1970

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Spray-applied rigid urethane foam was proposed by the contractor as form insulation for piers of a bridge structure on Project Number I 73101-068 in Saginaw County (S 15 of 73101, Tittabawassee Rd over I 675). Samples of the liquid components and coated panels were submitted to the Research Laboratory November 26, 1969 along with brochures describing application methods and materials. Recommendations concerning the proposed application were transmitted to R. L. Greenman, Engineer of Testing and Research, in a memorandum dated December 9, 1969. Following this memorandum the Research Laboratory was asked to evaluate the insulation effectiveness of rigid urethane foam as applied to steel forms on the above project.

This report summarizes the results of a field test using urethane foam insulated forms to protect fresh concrete in cold weather. One column of a bridge carrying Tittabawassee Rd over I 675 was selected to evaluate the thermal insulation efficiency of urethane foam as specified for low temperature protection with insulated forms (Section 5.01.14-C of 1967 MDSH Standard Specifications). The selected steel form was coated with sprayed-on layers of urethane foam using special gun-type equipment. Specifications require an insulating thickness of not less than 1.5 in. for concrete pours of more than 24 in. thickness. This minimum thickness is specified for polystyrene and insulating blankets with maximum thermal conductivity of 0.27 BTU per hour per square foot for a temperature gradient of one degree F per inch of thickness at mean temperature of 75 F (Section 7.24.04-g and h of 1967 MDSH Standard Specifications). Since a thermal conductivity of 0.11 is listed in the literature by urethane foam's manufacturers, the proposed insulating material should give an equivalent thermal insulation efficiency with an insulating thickness of 0.6 in. The specification requirements for this application, however, called for a minimum thickness of 1.5 in. Figure 1 shows the column with the insulating material in place.

Temperature Changes in Fresh Concrete

Concrete was placed into the insulated form at 11:15 a.m. on December 17, 1969. Fourteen temperature measuring thermocouples, located as shown in Figure 2, were read approximately every two hours, day and night, during the five days and six hours that the forms remained in place. The forms were removed at 6:00 p.m. on December 22.

Maximum and minimum values were selected from the data to compute mean daily temperatures in accordance with the specification requirements (Section 5.01.05-d). These mean daily temperatures are shown in Figure 3. By relating these mean temperature data with concrete age according to the table shown on page 311 of the 1967 Standard Specifications, the assumed values of concrete compressive strength shown in Figure 4 were obtained. Figures 3 and 4 indicate that:

1. After the first four days of curing, mean daily temperatures less than 40 F were recorded at thermocouples 1, 2, 3, placed on the top surface beneath 5 to 6 in. of straw, and thermocouples 11, 12 and 14, located at the bottom of the column. A mean daily temperature of 40 F is considered the acceptable minimum during the hardening period of fresh concrete (Fig. 3).

2. Based on the assumed daily percentage increase in compressive strength as specified in the above referenced table, the minimum 50 percent of concrete design strength was apparently not attained at either the top or the bottom of the column at the end of 5-1/4 days when the forms were removed (Fig. 4). However, 50 percent or more of the specified compressive strength was attained near the surface under the insulating material (thermocouples 4, 5, 8, and 9) and at the center (thermocouples 6, 7, and 10).

3. Based on the same table, the assumed 70 percent of compressive strength was not attained at any of the 14 thermocouple locations during the 5-1/4 day curing period.

Insulation Thickness and Density

Urethane insulation efficiency and cost depend on the total thickness of the layers applied to the steel forms. Insulation thickness was measured at six random locations on the form. The specified 1.5 in. minimum thickness was not obtained at four of these locations. The measured values ranged from 0.7 in. to 1.7 in. with an average of 1.3 in. This large variation in thickness indicates that the spray technique as used in the field is a major factor to be considered in the cost-benefit value of the urethane insulation practice. Also, insulation efficiency and adhesion vary with the density of the sprayed-on layers and surface preparation of the steel forms. Urethane density values (not specified in 1967 MDSH Standard Specifications) determined from six random samples of the insulating material, ranged from 2.3 to 3.6 lb per cu ft with an average of 3.0 lb per cu ft. This large variation in density is an indication of another problem apparently characteristic of this type of insulation and the method of its application.

Steel Surface Preparation

The present method of applying sprayed-on insulation is to coat the half-round form sections before assembling and erecting. Insulation breakdown after form assembly, is shown in Figure 1. It was found necessary on this project to wrap metal wires around the column to hold the urethane in place. This indicates that careful surface preparation or some other way of achieving adhesion is required before making the sprayed applications of urethane.

Recommendations

Since the resulting urethane insulation as applied to the selected steel form did not meet the minimum thickness requirements, an additional field experiment is recommended with the following special provisions:

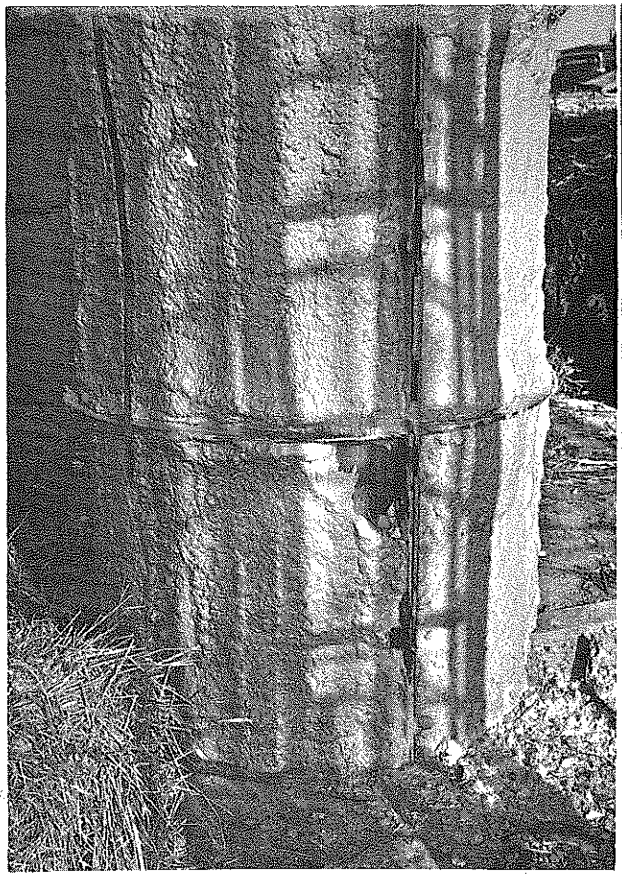
1. In order to evaluate the effectiveness of the urethane insulation compared to polystyrene and insulating blankets it is proposed that on a future field study two pier columns be poured at the same time, one with urethane insulation and the other with polystyrene or insulating blankets. Temperatures should be monitored in both columns to determine which material best serves to insulate the concrete.

2. Acceptance of assembled, insulated forms for use should be based on the results of at least 10 thickness measurements taken at random locations designated by the Engineer. These thickness measurements may be rapidly obtained by using a graduated needle. The minimum specified thickness of 1.5 in. should be obtained at every location.

3. The applied urethane foam should adhere tightly to all exterior steel surfaces including the steel flanges. After assembly, all bolts and seams are to be urethane-coated to specifications.

4. Additional heat protection or extra insulation should be applied at the top and the bottom of the column, especially when air temperatures below 40 F are expected. This is not only true with urethane insulation but also with insulated blankets; both types of materials require better protection at these locations as shown previously in Research Laboratory Report No. R-417.

The results of this additional experiment will indicate whether acceptable insulation performance can be obtained with urethane insulating material.



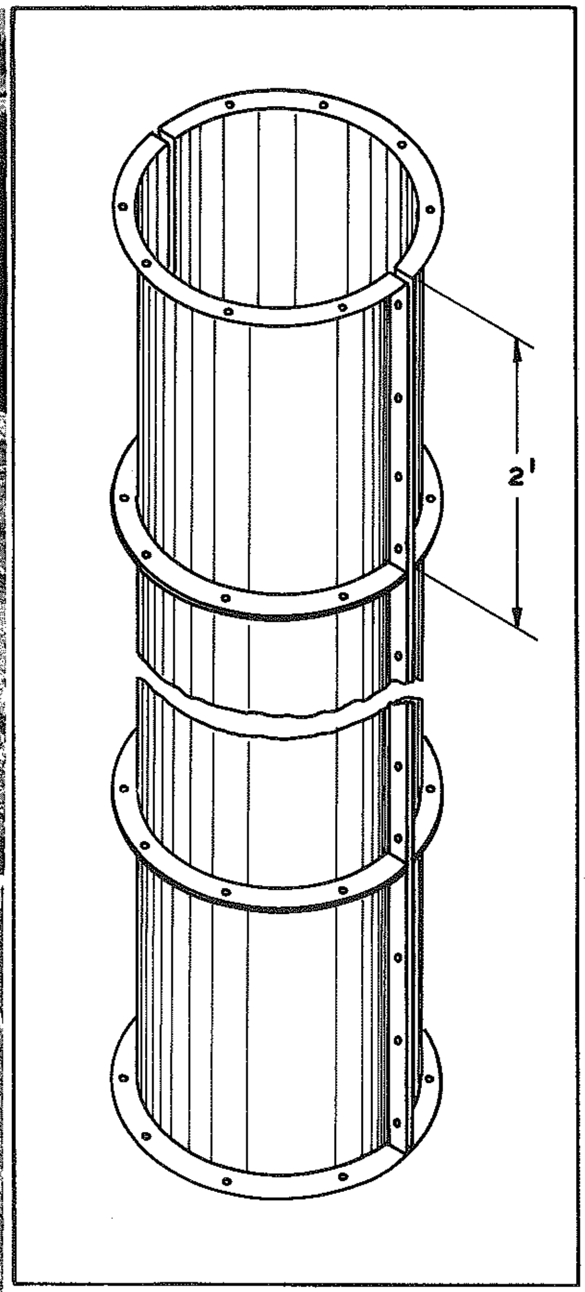


Figure 1. Steel column form (above), with foam applied (top left). Note tie wires (lower left).

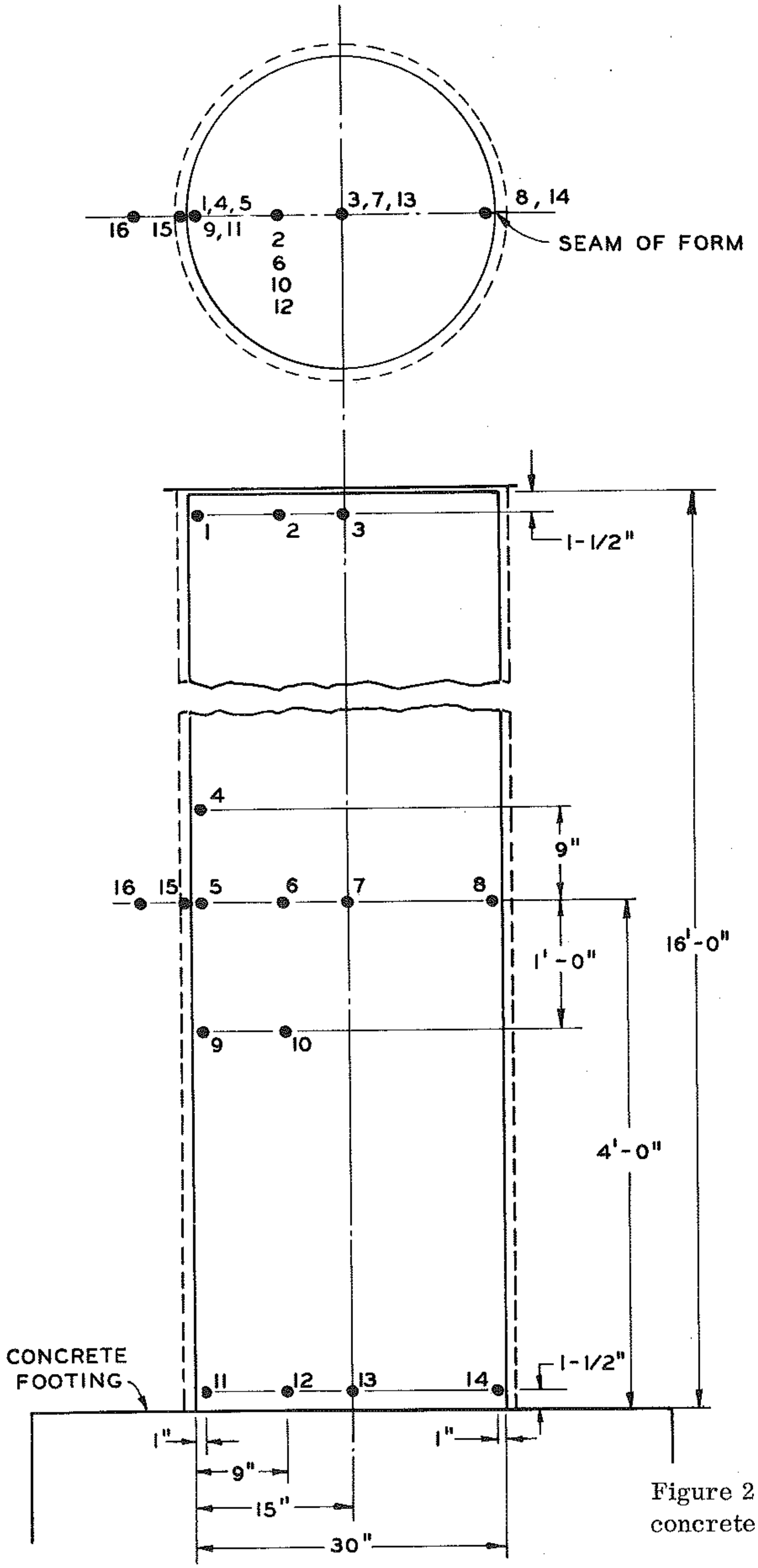


Figure 2. Thermocouple locations in concrete column.

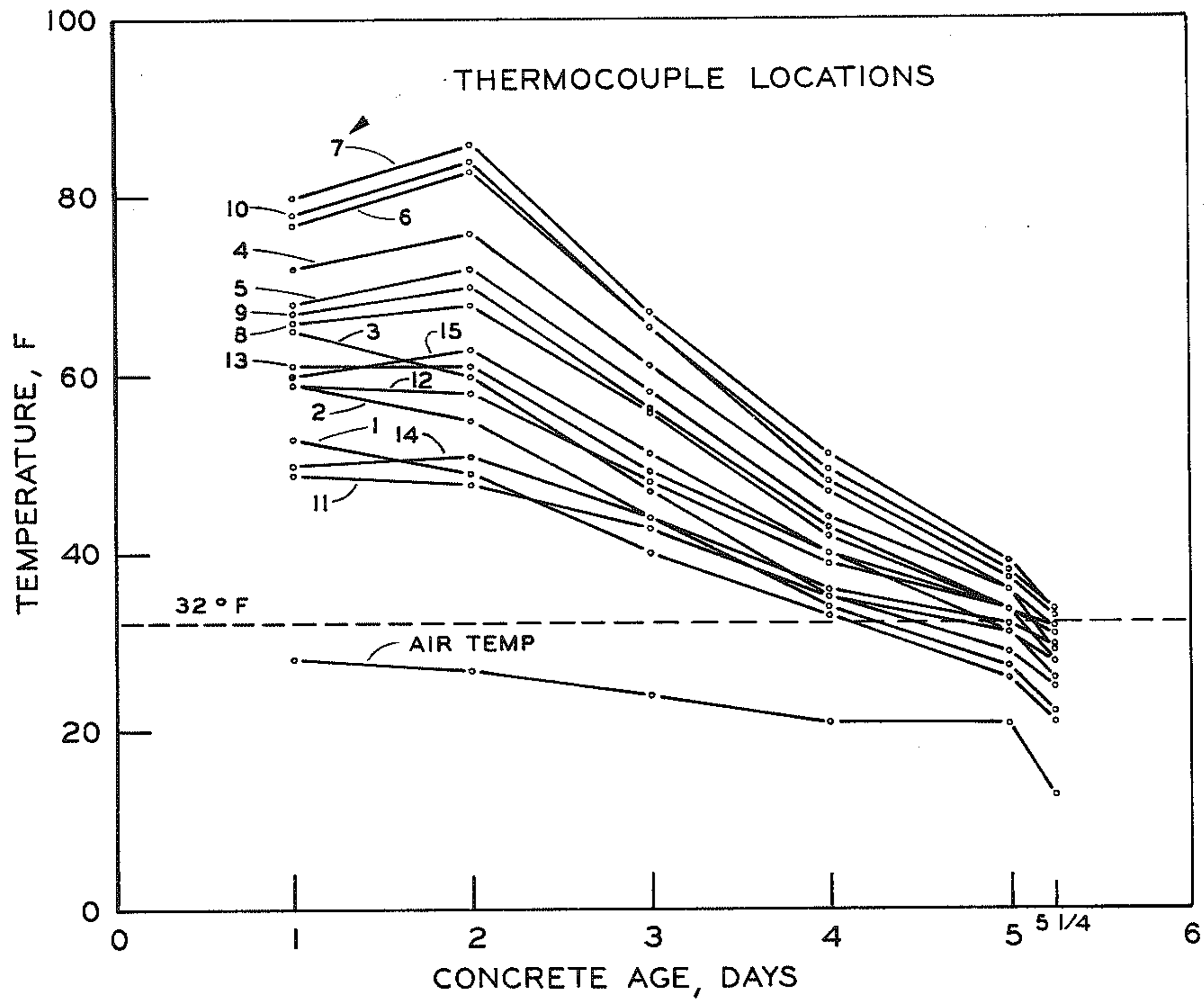


Figure 3. Mean daily temperature changes in a concrete column due to heat liberation during hardening of fresh concrete (12-17-69 to 12-22-69).

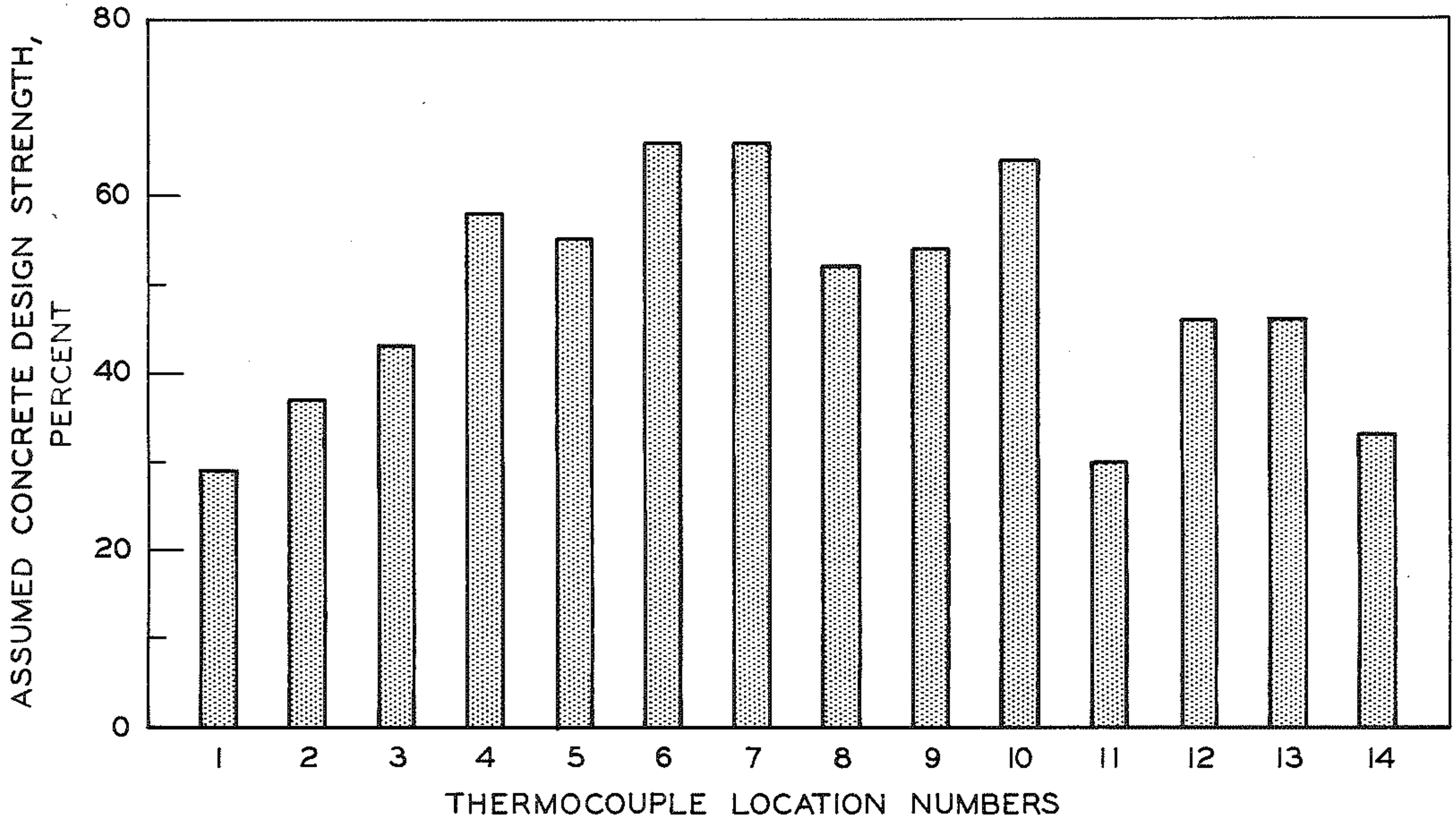


Figure 4. Assumed percentage of concrete compressive strength attained at the end of 5 1/4 days when forms were removed.