PROTECTED B

NRC·CNRC CONSTRUCTION

Testing Concrete Slabs according to S115 Standard

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Report No.: A1-016259.1
Report Date: 28 November 2019
Contract No.: A1-016259
Agreement Date: 13 August 2019

National Research Council Canada
Conseil national de recherches Canada

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Executive Summary

Université Laval was interested to get information on the behaviour of a concrete slab with two openings during fire. A fire test was conducted in the intermediate furnace at the National Research Council (NRC) following the CAN/ULC-S115 standard. The results showed that, filling one of the openings with rock (mineral) fiber successfully limited the heat transfer from the exposed surface to the unexposed surface and kept the temperature of the unexposed surface below the temperature limits stated in the standard.

1 Introduction

Université Laval (the client) was interested in conducting a fire test on a concrete slab assembly in the intermediate-scale furnace at NRC following the CAN/ULC-S115 standard. The aim of the project was to provide information on the behaviour of the slab during the fire test. The slab was prepared by the client and delivered to NRC. Instrumentation and testing were conducted by NRC staff in the fire safety laboratory at M59.

2 Test Specimen

The test specimen was a concrete slab assembly with two through-slab accesses (also known as "bride of Mainguy") prepared by the client. The dimensions of the slab were 133.4 cm wide by 133.4 cm high by 20.3 cm thick (52.5" by 52.5"by 8"). It had two through-slab access openings, each fitted with a cover of 25.5 cm (10"). A schematic figure of the slab with the exact location of the openings is presented in figure 1. One of the opening accesses beneath the cover was filled with 3 layers of rock (mineral) wool from AFB® and the other one was left without insulation beneath the cover. The rock wool was compressed at 30%. Four hooks were used as supporters to maintain the rock wool in its place. The hooks were folded and fixed at the corners and on the screws of the bride of Mainguy. Figure 2 shows a schematic diagram of the rock wool in the opening.

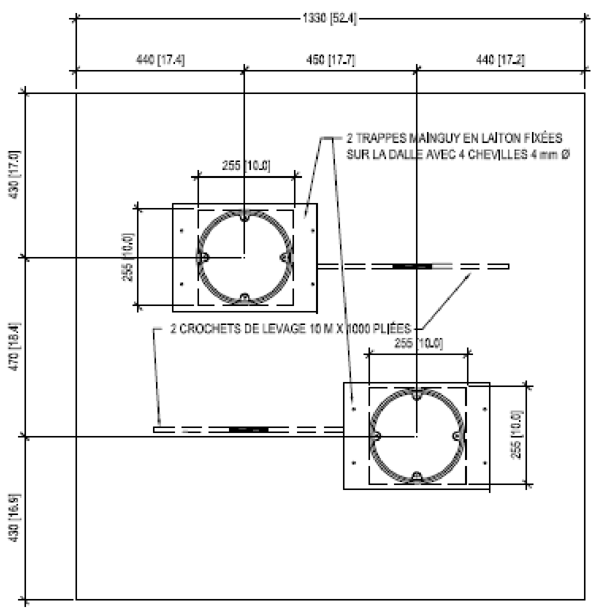


Figure 1. Schematic figure of the slab with all dimensions in mm (inch)

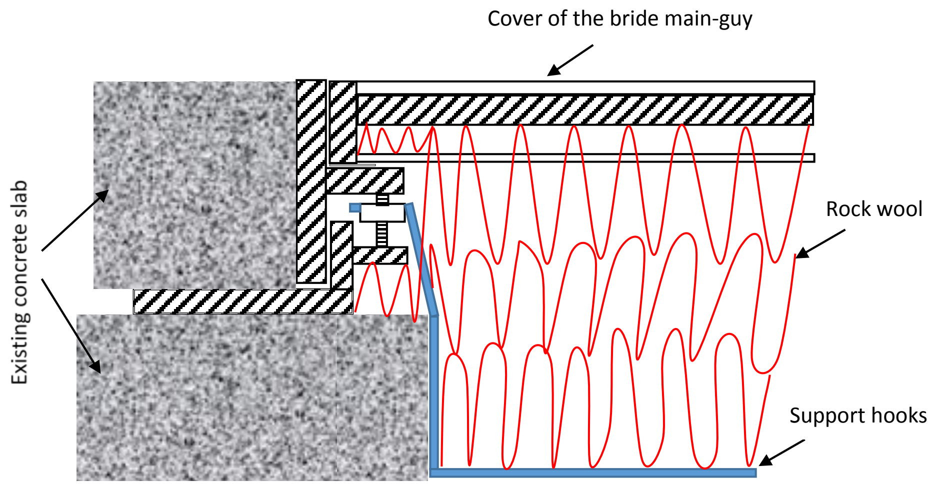


Figure 2. A schematic diagram of the rock wool (red curves) arrangement inside the hole. The blues line represents the support hooks

Figures 3(a) and (b) show respectively photos of the slab from unexposed and exposed sides when delivered to NRC. Some of the rock wool and the supporting hooks can be seen in figure 3(b).

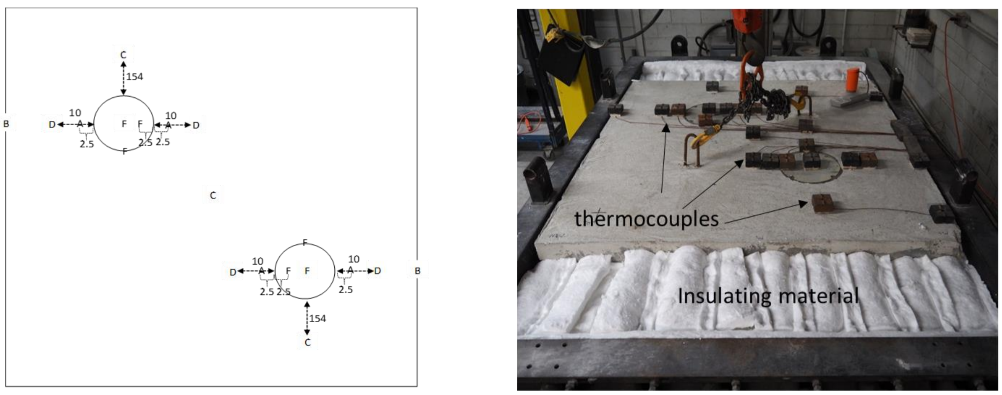
Figure 3. Photos of the slab when delivered to NRC

3 Testing Procedures

3.1 Instrumentation

Thermocouples (TCs) were installed on the unexposed surface of the slab in accordance with CAN/ULC-S115. A total of 19 TCs were used and their locations are shown in Figure 4; where;

- A: 2.5 cm from penetrant (opening) periphery from both sides
- B: on periphery of specimen
- C: center of the slab and at 154 cm between penetrant (opening) and the periphery of the specimen
- D: at 10 cm from penetrant (opening)
- F: on unexposed surface of penetrant (opening) (at center, at 2.5 cm from circumference and on periphery)



(a) (b)

Figure 4. (a) Schematic diagram of the TC locations (dimensions in cm). (b) Photo of the slab inside the furnace with the TCs on the unexposed surface

3.2 Furnace

The slab was tested in the intermediate-scale furnace at NRC. One side of the slab was exposed to the fire prescribed by CAN/ULC-S115. The NRC intermediate-scale furnace has a fire chamber where specimens up to a maximum size of 135 cm (53 in) by 198 cm (78 in) can be tested. The temperatures in the intermediate-scale furnace were measured using four Type K chromel-alumel thermocouples. The average temperatures measured by the furnace thermocouples was used to automatically control the furnace temperature. The standard temperature curve and the average temperature inside the furnace are presented in Figure 5. A pressure probe was placed at 43 cm below the exposed surface to measure the pressure gauge inside the furnace.

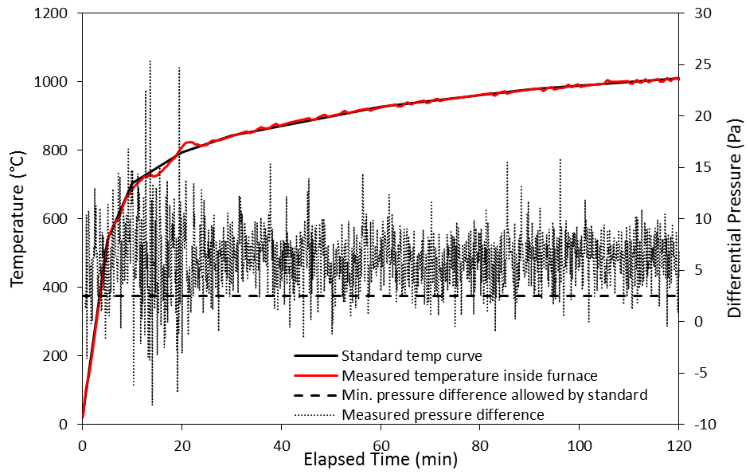


Figure 5. Temperature Curve as per CAN/ULC-S115 (black line) vs average furnace temperature (red line). Measured ΔP inside the furnace (dotted line) vs min. required ΔP

3.3 Test

The relative humidity of the specimen was measured before and after conducting the test. After instrumentation, the slab was placed horizontally in the furnace, and any gap around the slab edge was filled with insulation to keep the heat inside the furnace while testing. Before the test, the air velocity above the slab was measured using anemometer to ensure it did not exceed 1.3 m/s as required by the standard.

During the test, a minimum pressure difference (ΔP) of 2.5 Pa was maintained between the exposed and unexposed surface as required by the standard. The measured ΔP during the test time is presented in figure 5. The readings of the thermocouples were recorded at an interval of 5 s and the unexposed surface was monitored using a camera installed close to the top side of the slab.

According to CAN/ULC-S115, the heat transfer through the slab during the test should not allow the rise of the temperature of any of the thermocouples on the unexposed surface above 181°C above the initial temperature. The test was conducted for two hours.

4 Results and Observations

The test was conducted on 24th of September 2019. The measured relative humidity of the specimen was 83.7% and 83.2% before and after the test, respectively. Table 1 shows the main incidents observed during the test. Spalling, characterized by its sound, was detected at 9:36 min from the start of the test. Steam was observed coming out from the non-insulated (empty) opening at 16:50 min. This steam was a result of the drying of the concrete.

Table 1. Observations during the test

Exposure Time **(HH:MM:SS)**	Observations
00:00	Test was started
09:36	Spalling sound was detected
12:33	Temperature at center of the cover of the non-insulated opening reached failing criteria (207.5°C)
16:50	Steam was seen out of the non-insulated opening
26:10	The cover on top of the non-insulated opening partially lifted up
1:49:05	The top of the non-insulated opening (below the cover) started glowing
2:00:00	Test was stopped

Figures 6 to 8 show the temperatures measured by the thermocouples placed on the unexposed surface of the slab. The initial temperature of the unexposed surface was 25°C, thus the failure temperature according to CAN/ULC-S115 should be 206°C. This temperature is presented in figures 6 to 8 as the black dashed line. It can be clearly seen in Figure 6 that five temperature measurements on the surface of the non-insulated (empty) opening exceeded the failure temperature. The three highest temperatures were: the temperature at the center of the opening cover (reached 207°C at 12.5 min), followed by the temperature at 2.5 cm from the periphery (exceeded the failure temperature at 15 min), then the temperature at the opening periphery (exceeded the failure temperature at 40 min). It is worth noting that, the cover of the non-insulated opening started to lift up at 26 min and the surface below started to glow at 109 min. Figure 9 shows a photo of the lifted-up cap near the end of the test and the glowing surface below it.

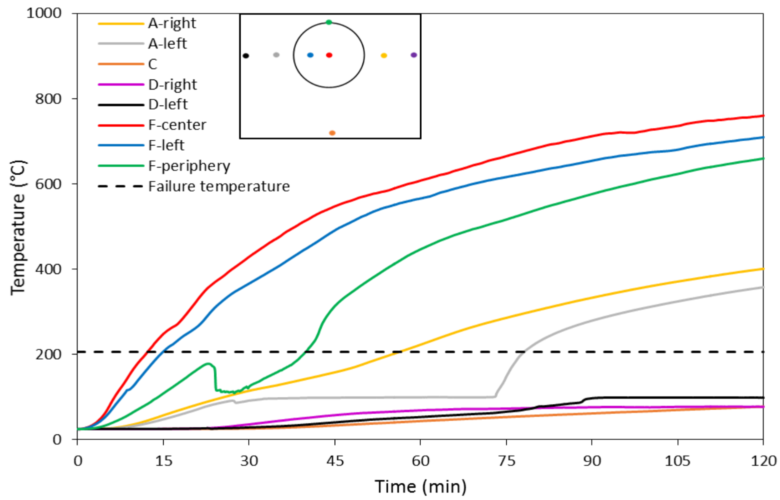


Figure 6. Temperatures on and around the non-insulated opening. The inset represents a colored schematic of the locations of thermocouples. Refer to figure 4(a) for the exact locations

On the other hand, figure 7 shows that the temperatures on the surface of the insulated opening (filled with rock fiber) which didn't reach the failure temperature. The maximum temperature during the test (2 hrs) was 94.4°C at the center of the opening cover. Thus, the rock fiber successfully limited the heat transfer from the exposed surface to the unexposed surface and prevented the rise of the temperature of the unexposed surface above the failure temperature. Figure 8 shows the temperatures at the center of the slab and on the periphery (B-locations in figure 4(a)). The temperatures at these locations didn't reach the failure temperature as seen in the figure. The maximum temperature was 61.5°C at the center of the slab.

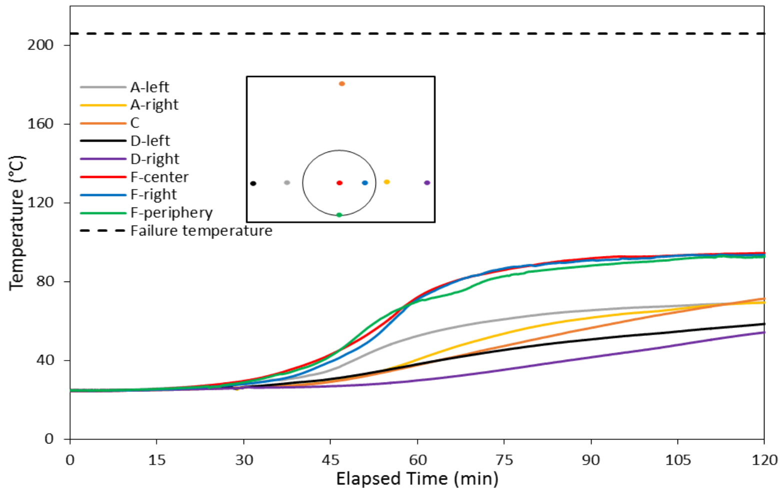


Figure 7. Temperatures on and around the insulated opening. The inset represents a colored schematic of the locations of thermocouples. Refer to figure 4(a) for exact locations

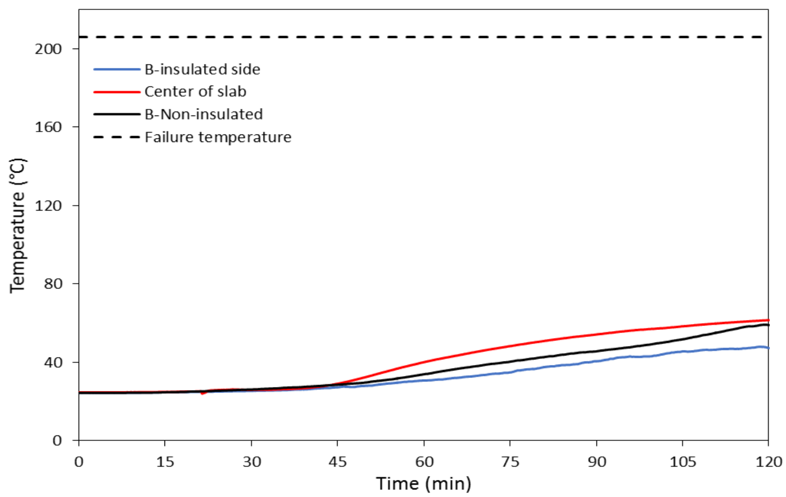


Figure 8. Temperatures at center of the slab and B-locations in figure 4(a)

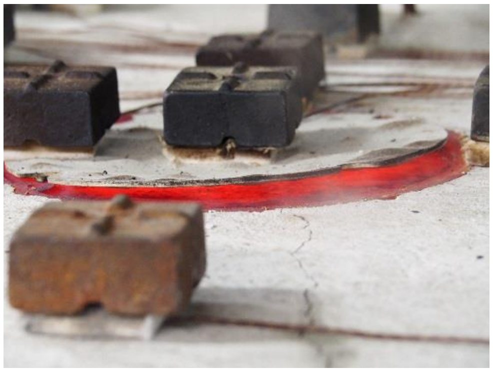


Figure 9. A photo showing the lift-up of the cap of the non-insulated opening and the glowing surface below it.

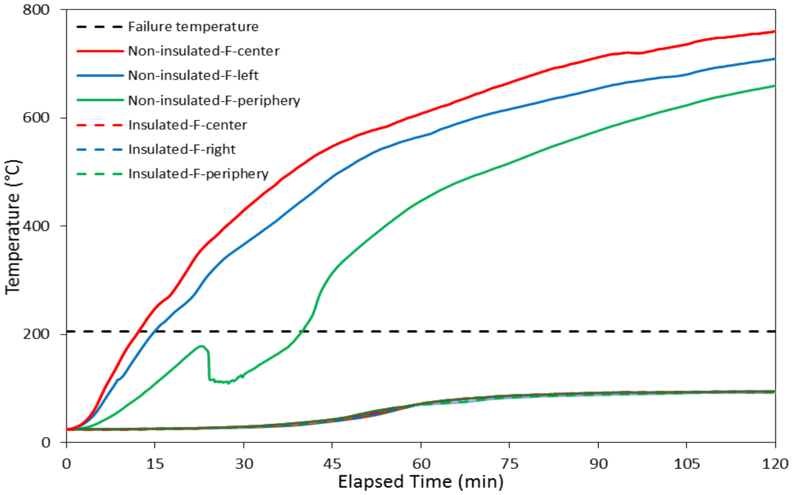


Figure 10. Comparison of the maximum temperatures on the insulated and non-insulated openings.

Figure 10 compares the maximum temperatures on the unexposed surface of the insulated and non-insulated openings. Three temperatures are shown for each of the openings: at center of the opening cover, 2.5 cm from the periphery and periphery. The figure clearly shows the effectiveness of the rock fiber in limiting the heat transfer across the slab and avoiding the rise of the surface temperature above the failure temperature.

Figure 11 shows the exposed surface of the slab before and after the test. A lot of damage can be seen on the surface after the test. Moreover, some cracks can be seen near the insulated opening. Even though, the temperatures on the unexposed surface above the insulated opening were kept below the failure temperature as a result of using the rock fiber.

Although some of the rock fibre can be seen out of the insulated opening, none of it fell down in the furnace.

Before After

Figure 11. Photos of the exposed surface of the slab before and after the test.

The unexposed surface of the slab after the test is shown in figure 12. Much less damage can be seen on the cover of the insulated opening compared to the non-insulated one.

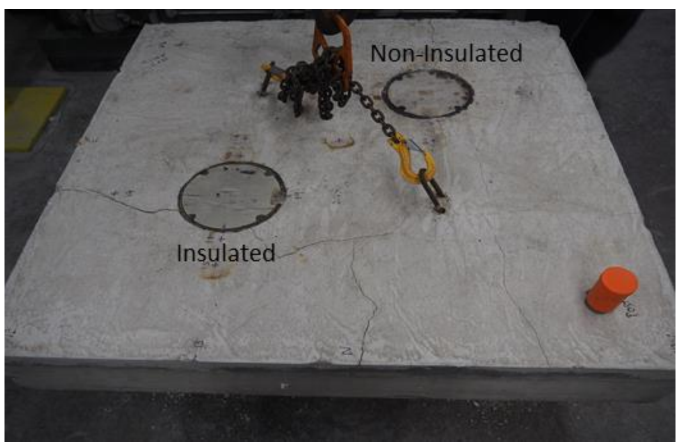


Figure 12. Unexposed surface of the slab after the test.

5 Summary and Conclusions

Based on the observations and measurements, it can be concluded that,

- Keeping the opening empty (non-insulated) allowed the transfer of heat to the unexposed surface. Accordingly, the temperature of the unexposed surface above the non-insulated opening exceeded the failure temperature of CAN/ULC-S115.
- Filling the opening with 30% compressed rock fibre successfully kept the temperature of the unexposed surface below the failure temperature of CAN/ULC-S115.

Acknowledgments

The author would like to acknowledge the support of Dr. Noureddine Bénichou, and NRC's technical staff: Patrice Leroux, Robert Berzins, Karl Gratton, Andrew Frade and Pier-Simon Lafrance.

References

CAN/ULC-S115-2018, Standard Method of Fire Tests of Firestop Systems, Fifth Edition, Standards Council of Canada, Canada, 2018.