CHAPTER 4: RESULTS

4.1 Outdoor Temperature Measurements

Temperature measurements were conducted on the outdoor temperature specimen from July 1997 to June 1998. As stated in section 3.1.2, the purpose of this experiment was to determine the maximum and minimum field temperatures that the polymer concrete and aluminum achieve when exposed to typical Virginia weather conditions. Temperature readings were taken from three locations on the beam. At each location, readings were taken at the top surface of the overlay, at the interface between the overlay and the aluminum, and at the bottom of the aluminum surface of the top flange. Ambient temperature readings were also taken at approximately 51 mm [2 in] above the center of the beam.

The maximum temperatures were obtained on July 28, 1997. The maximum temperature at the top surface of the overlay was 51 ^{O}C [124 ^{O}F]. The bottom surface of the aluminum of the top flange achieved a maximum temperature of 52 ^{O}C [126 ^{O}F]. The interface between the overlay and the aluminum had the highest maximum temperature at 53 ^{O}C [127 ^{O}F]. All of these temperatures were obtained at 4:00 P.M., the maximum ambient temperature measured was
42 ^{O}C [107 ^{O}F]. The actual maximum air temperature on that day was 36 ^{O}C [97 ^{O}F]. Figure 10 presents the temperature measurements for July 18, 1997.

The minimum temperatures were obtained on March 12, 1998. The same minimum temperature of -17 ^{O}C [2 ^{O}F] was obtained for the overlay surface, interface, and aluminum. This temperature was achieved at 6:30 A.M. with a minimum ambient temperature measured at -15 ^{O}C [5 ^{O}F]. Figure 11 presents the temperature measurements for March 12, 1998.

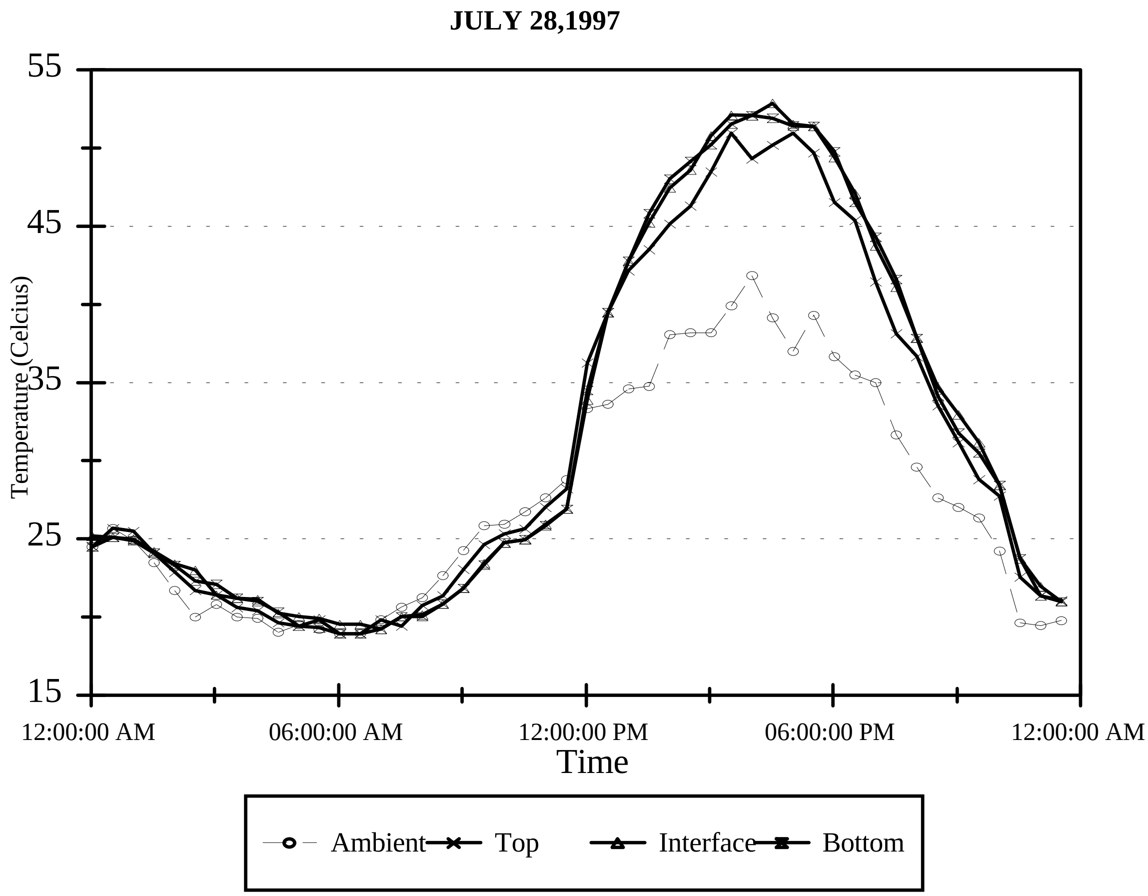

Figure 10: Temperature Readings for July 28, 1997

March 12, 1998

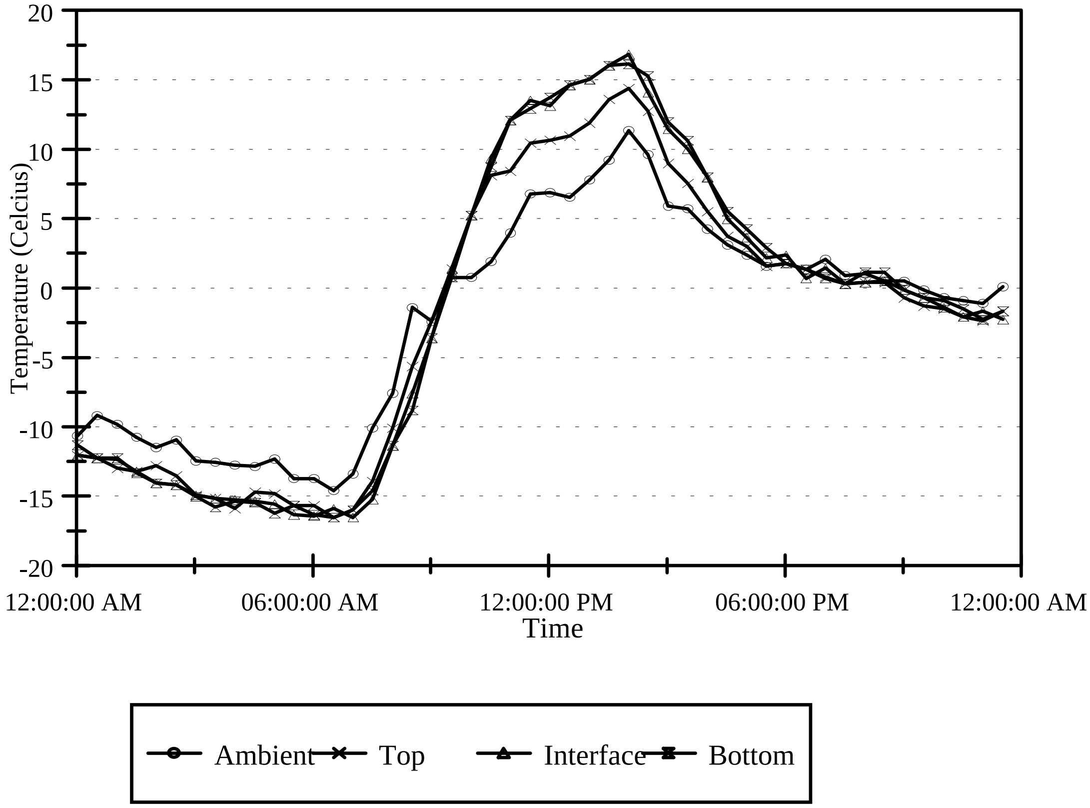

Figure 11: Temperature Readings for March 12, 1998

4.2 Control Specimens

In October 1997, testing of the control specimens was initiated. The specimens were tested in three groups. Control group 1 was precracked at room temperature and plastic deformation of the aluminum occurred during the precracking of the polymer concrete/aluminum substrate bond. The specimens were then placed in dry ice for 6 hours before MMF testing. Each specimen was removed from the dry ice and side 1 was tested. The specimen was then flipped and side 2 was tested. A total of eight specimens were tested for control group 1, thus there was a possibility of obtaining 16 G_{cr} values, one G_{cr} value from each side of each specimen. A total of twelve from the possible sixteen measurements were recorded as an acceptable failure mode, with acceptable failure mode meaning failure at the primary interface. The individual measurements were somewhat variable. Figure 12 presents the location of the primary interface.

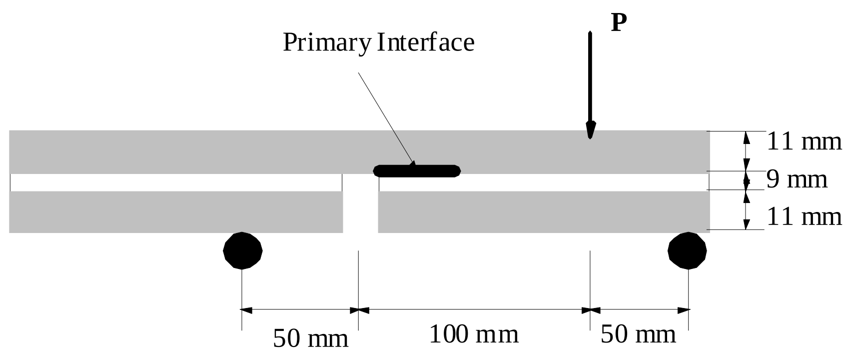

Figure 12: Primary Interface Location

The second control group specimens were placed in dry ice before precracking. Each specimen was removed from the dry ice and precracked, the aluminum did not plastically deform. Before MMF testing the specimens were placed back in the dry ice. The specimens were then tested in the same manner as control group 1. A total of eight specimens were tested in the second control group. A total of 16 measurements were recorded for the second control group and the variability was slightly less. The third control group specimens were precracked and tested in the same manner as control group 2. However, after testing side 1 of the specimen, it was returned to the dry ice in order to return the specimen to the dry ice temperature. After the specimen was returned to the initial test temperature of -33 ^{O}C [-27 ^{O}F], side 2 was tested. Five measurements were obtained from this test group with less variability than the first two test groups. All subsequent testing was conducted using the procedure used for the third control group. Table 2 presents the descriptive statistics for the three control groups. The means represent the critical strain energy release rate, G_{cr}, [J/m^2].

Table 2: Descriptive Statistics for Control Groups

Test Group	Number of Tests	Mean [J/m^2]	Standard Deviation	Coefficient of Variation [%]
Control Group 1	12	136	16.9	12.4
Control Group 2	16	125	14.8	11.8
Control Group 3	5	104	7.7	7.5

4.3 Humidity Chamber Specimens

As stated in section 3.3.1, specimens were conditioned in three different chambers at three different temperatures, 30 ^{O}C [86 ^{O}F], 45 ^{O}C [113 ^{O}F] and 60 ^{O}C [140 ^{O}F]. Each chamber was at 98% relative humidity.

A total of thirty-three measurements were recorded as an acceptable failure mode for the 30 ^{O}C [86 ^{O}F] humidity chamber specimens. Most of the test specimens failed at the primary interface, others failed within the polymer concrete overlay. Seven specimens were tested after 6 and 9 months of conditioning, and six specimens were tested after 12 months of conditioning.

The average critical strain energy release rate, G_{cr}, for the specimens tested after 6 months of conditioning was 115 J/m^2. The average G_{cr} for the specimens tested after 9 months of conditioning was 76 J/m^2, and the average G_{cr} for the specimens tested after 12 months of conditioning was 68 J/m^2. Table 3 presents the descriptive statistics for the 30 ^{O}C [86 ^{O}F] humidity chamber specimens.

Table 3: Descriptive Statistics for Humidity Chamber Specimens at 30 ^{O}C [86 ^{O}F]

Conditioning Time	Number of Tests	Mean [J/m^2]	Standard Deviation	Coefficient of Variation [%]
6 Months	14	115	14.8	12.9
9 Months	12	76	11.0	14.5
12 Months	7	68	8.6	12.7

The 45 ^{O}C [113 ^{O}F] humidity chamber specimens yielded twenty-seven measurements from the possible forty measurements. The specimens tested after 6 months of conditioning all failed at the primary interface. However, thirteen of the measurements from the specimens tested after 9 and 12 months of conditioning failed at the interface between the overlay and the top aluminum plate rather than the bond being evaluated, or they failed within the polymer concrete overlay. Thus only thirteen of the possible twenty-six measurements were recorded as an acceptable failure mode. The average G_{cr} values were 91, 73 and 66 J/m^2 for the specimens tested after 6, 9 and 12 months of conditioning, respectively. Table 4 presents the descriptive statistics for the 45 ^{O}C [113 ^{O}F] humidity chamber specimens.

Table 4: Descriptive Statistics for Humidity Chamber Specimens at 45 ^{O}C [113 ^{O}F]

Conditioning Time	Number of Tests	Mean [J/m^2]	Standard Deviation	Coefficient of Variation [%]
6 Months	14	91	17.5	19.2
9 Months	7	73	12.9	17.7
12 Months	6	66	11.5	17.4

Many problems were encountered with the 60 ^{O}C [140 ^{O}F] humidity chamber specimens. Only five of the possible fourteen measurements were recorded as an acceptable failure mode for the specimens tested after 6 months of conditioning. None of the specimens tested after 9 and 12 months of conditioning failed at the primary interface. Failure of most of these specimens occurred within the polymer concrete overlay. Further discussion of these specimens will follow in section 6.3. Table 5 presents the descriptive statistics for the 6 month, 60 ^{O}C [140 ^{O}F] humidity chamber specimens.

Table 5: Descriptive Statistics for Humidity Chamber Specimens at 60 ^{O}C [140 ^{O}F]

Conditioning Time	Number of Tests	Mean [J/m^2]	Standard Deviation	Coefficient of Variation [%]
6 Months	5	76	17.9	23.6

4.4 Freezing and Thawing Specimens

In November 1997, five freezing and thawing (F&T) conditioned specimens were tested, the specimens had been exposed to 70 F&T cycles prior to testing. Difficulties occurred in the testing of these specimens when some of them failed at the interface between the polymer concrete overlay and the aluminum plate bonded to the top of the overlay. A total of six specimens were tested. Only five of the possible twelve measurements were recorded as an acceptable failure mode. The average G_{cr} value was 112 J/m^2. In March 1998, seven specimens were tested after being exposed to 182 F&T cycles. Of the possible fourteen measurements, thirteen were recorded as an acceptable failure mode. The average G_{cr} value was 75 J/m^2. After 300 cycles of conditioning, seven specimens were tested, thirteen out of a possible fourteen measurements were recorded as an acceptable failure mode. The average G_{cr} was 57 J/m^2. Table 6 presents the descriptive statistics for the F&T specimens.

Table 6: Descriptive Statistics for Freezing and Thawing Specimens

Conditioning Time	Number of Tests	Mean [J/m^2]	Standard Deviation	Coefficient of Variation [%]
70 Cycles	5	112	24.3	21.7
182 Cycles	13	75	12.6	16.8
300 Cycles	13	57	6.2	10.9

4.5 Salt Water Soak Specimens

Salt water soak (SWS) specimens were tested in December 1997 and March 1998 after 2 and 6 months conditioning, respectively. A total of five specimens were tested after 2 months of conditioning. Only six of the possible ten measurements were recorded as an acceptable failure mode for the specimens tested. The failure again occurred at the top aluminum plate/polymer concrete interface. The average G_{cr} value was 102 J/m^2. A total of seven specimens were tested after 6 months of conditioning. All fourteen measurements of the specimens were recorded as an acceptable failure mode. The average G_{cr} value was 100 J/m^2. After 12 months of conditioning, seven specimens were tested. All fourteen measurements were unacceptable failure modes. All of the failures occurred within the polymer concrete overlay. Table 7 presents the descriptive statistics for the salt water soak specimens.

Table 7: Descriptive Statistics for Salt Water Soak Specimens

Conditioning Time	Number of Tests	Mean [J/m^2]	Standard Deviation	Coefficient of Variation [%]
2 Months	6	102	11.9	11.7
6 Months	14	100	19.9	19.9

4.6 Dry Conditioning Specimens

In March 1998, eight specimens that had been dried at 60 ^{O}C [140 ^{O}F] for 6 months were tested. All of the sixteen measurements recorded were acceptable failure modes. The average G_{cr} value was 202 J/m^2. Table 8 presents the descriptive statistics for the dry conditioning specimens.

Table 8: Descriptive Statistics for Dry Specimens

Conditioning Time	Number of Tests	Mean [J/m^2]	Standard Deviation	Coefficient of Variation [%]
6 Months	16	202	35.2	17.4

4.7 Aluminum

Dogbone specimens cut from the bottom flange of the beams according to dimensions in ASTM B557. The specimens were tested in tension to determine the modulus of elasticity of the material. Three specimens were tested with all three test results yielding a modulus of elasticity of 68 GPA. This value corresponds to the modulus of elasticity reported in section 3.4.1.

4.8 Polymer Concrete

Modulus of elasticity was determined from polymer concrete specimens prepared by Reynolds Metals. The specimens were tested by Huiying Zhang at room temperature and also at -33 ^{O}C [-27 ^{O}F]. The latter temperature is the test temperature of the specimens being tested in the modified MMF test. The modulus of elasticity was 5.1 GPA at room temperature and 9.2 GPA at -33 ^{O}C [-27 ^{O}F]. These modulus of elasticity values are within the range of 6 to 10 GPa for typical polymer concretes [14].