

Effects of moisture on the mechanical properties of M70 Adhesive

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Background

Design of bonded structures must consider both the short term and long term performance of the joint. The short-term performance is often the subject of quantitative design analyses using Finite Element Modelling where material properties can be determined and applied. Long-term performance is predicted from the de-rating of the performance of conditioned test specimens. FEM could be used to predict performance of exposed structures if allowances can be made for the degradation of material properties due to exposure.

One of the most common chemicals that adhesive joints will encounter is water. Even if the moisture has no effect on the adhesive-adherend interface, it will diffuse into the polymer, affecting the mechanical properties. In structural adhesives the effect of moisture is to lower the glass transition temperature and cause plasticisation of the adhesive. The effects on flexible adhesives are not so well defined.

In order to investigate the effects of adsorbed moisture on the mechanical performance a number of tensile specimens of the elastomeric adhesive Evode M70 were immersed in distilled water at room temperature for 11 months. The effects of moisture adsorption on the mechanical properties are discussed in this paper.

Moisture Adsorption

Figure 1 shows the measured uptake of moisture during the immersion period. Plotted against linear time the rate of uptake slows at longer times, appearing to reach a plateau around 5% moisture uptake, suggestive of saturation. However, on a logarithmic time plot the adsorption curves appear linear with no indication of any plateau in moisture content.

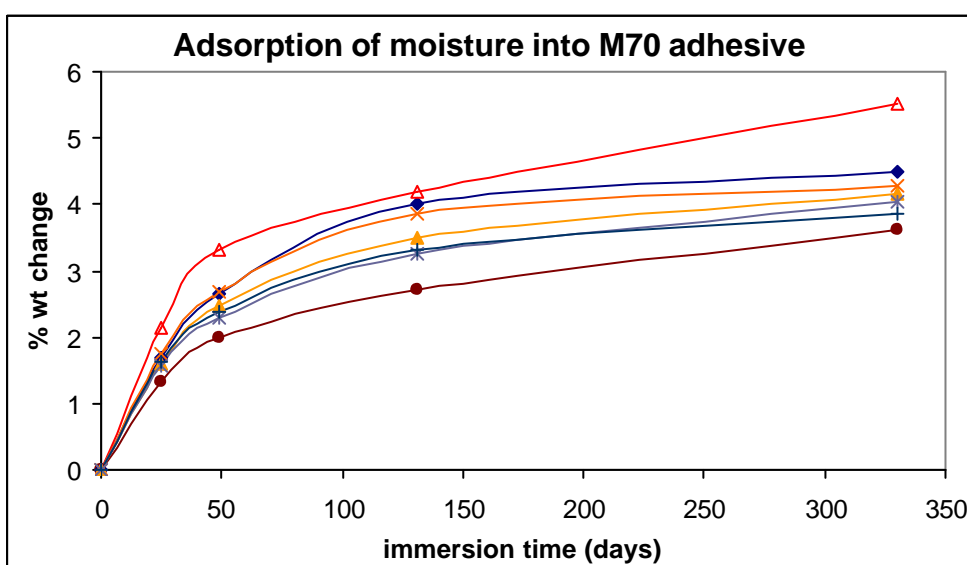


Figure 1: Moisture adsorption into M70 tensile specimens.

The scatter in the adsorption curves can be correlated with the initial weight of the specimens (proportional to thickness). The lower the initial weight (and thickness) the higher to relative moisture uptake. This is shown in Figure 2.

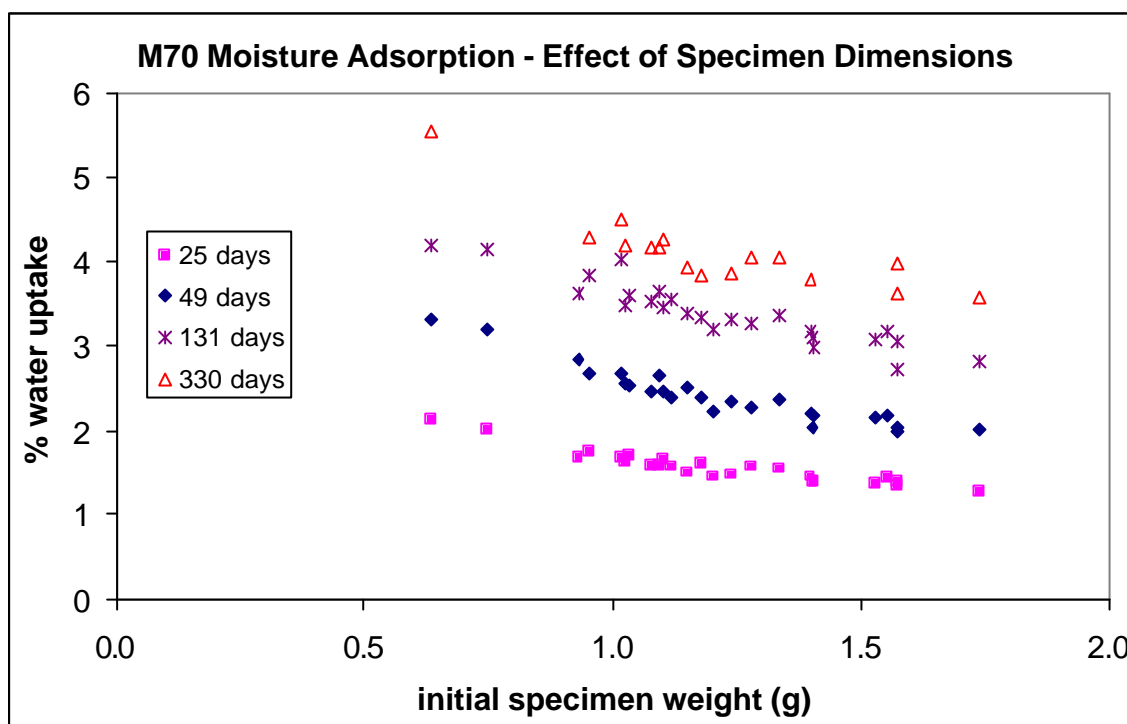


Figure 2: Effect of specimen size on moisture uptake.

If Figure 2 is re-plotted as moisture adsorption against the reciprocal of specimen mass the curves are approximately linear. This suggests first-order diffusion where the moisture concentration in the centre of the specimen is still much lower than at the edges of the specimens. Therefore, it is likely that the specimens are still below saturation. In an adhesive joint with a much smaller exposed area to adhesive volume, it is not likely that these levels of moisture content would be reached within a similar timescale.

Test Results

Temperature (°C)	Strain Rate (s ⁻¹)
0	3x10 ⁻³
20	3x10 ⁻⁴
20	3x10 ⁻³
20	3x10 ⁻²
40	3x10 ⁻³

The tensile specimens were tested under the conditions listed in Table 1. Axial and lateral strains were determined using a Messphysik video extensometer. Results are shown in Appendix A, Figures A1-A5 and Table A1. The average results for dry specimens are shown for comparison (Table A2).

Table 1: Tensile Test Conditions

The specimens were all tested after 330 days immersion. The level of adsorbed moisture was approximately 4-5%. There is good agreement between the results for specimens tested under the same conditions. Consistently, the specimens containing moisture appear stiffer than the corresponding dry specimens but fail at lower strains. This is opposite to the effects

that are observed in structural adhesives, such as AV119, where increasing moisture is accompanied by decreasing stiffness (however, strain to failure increases then decreases as moisture content increases). The reasons for this behaviour are not understood. The glass transition temperature determined using DMTA was $-26\text{ }^{\circ}\text{C}$, which is only slightly higher than the value of $-30\text{ }^{\circ}\text{C}$ obtained for the dry material.

The lateral strains determined in the tests on the specimens containing adsorbed moisture were significantly lower than in equivalent tests on the ‘dry’ material. This is apparent from the lower values obtained for Poisson’s ratio.

FEM of lap joint specimens performed using uniaxial and volumetric test data derived from the immersed specimens show, as expected, a large increase in predicted stiffness (Figure 3). No joint specimens were immersed in water to provide conditioned test specimens so it is not possible to confirm the suggestion that adsorption of moisture increases the joint stiffness.

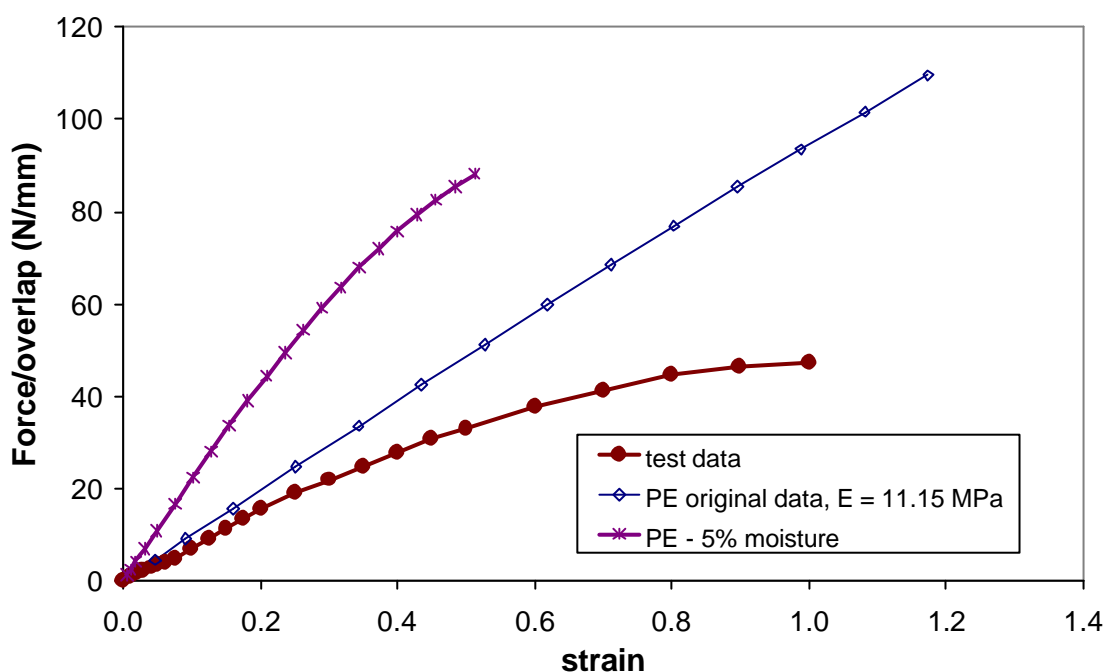


Figure 3: Effect of moisture on predicted lap joint performance

Concluding Remarks

The M70 adhesive appears capable of adsorbing reasonable quantities of water. Adsorbed water affects the hyperelastic properties of the material with increased stiffness but reduced strength and strain at failure observed in tensile test results obtained at different strain rates and temperatures.

Acknowledgements

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APPENDIX A: TENSILE RESULTS FOR EXPOSED M70 ADHESIVE

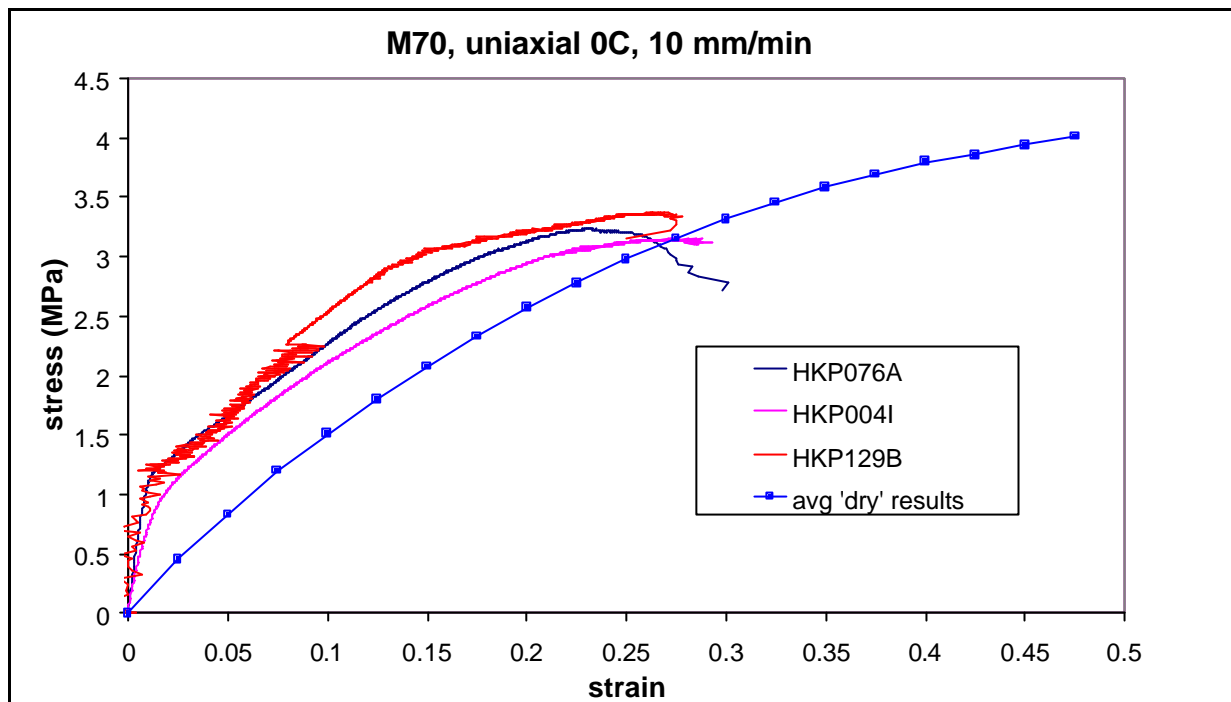


Figure A1: Tensile tests at 0 °C and 10 mm min⁻¹ (rate = 3x10⁻³ s⁻¹)

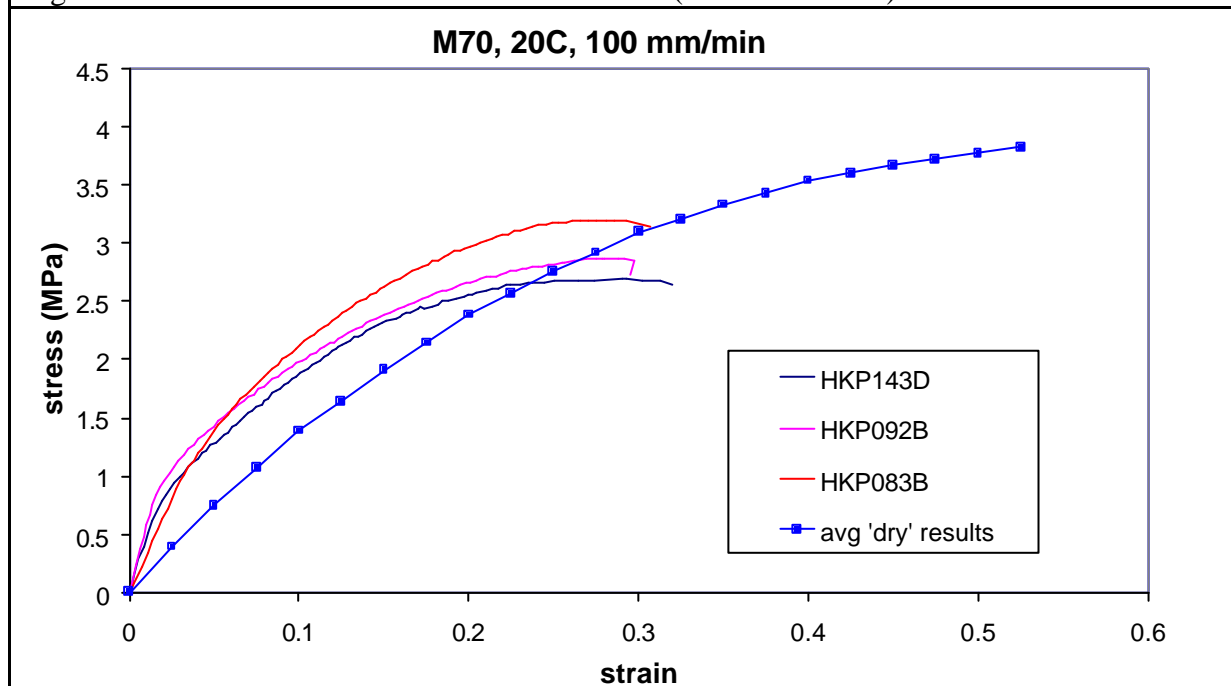


Figure A2: Tensile tests at 20 °C and 100 mm min⁻¹ (rate = 3x10⁻² s⁻¹)

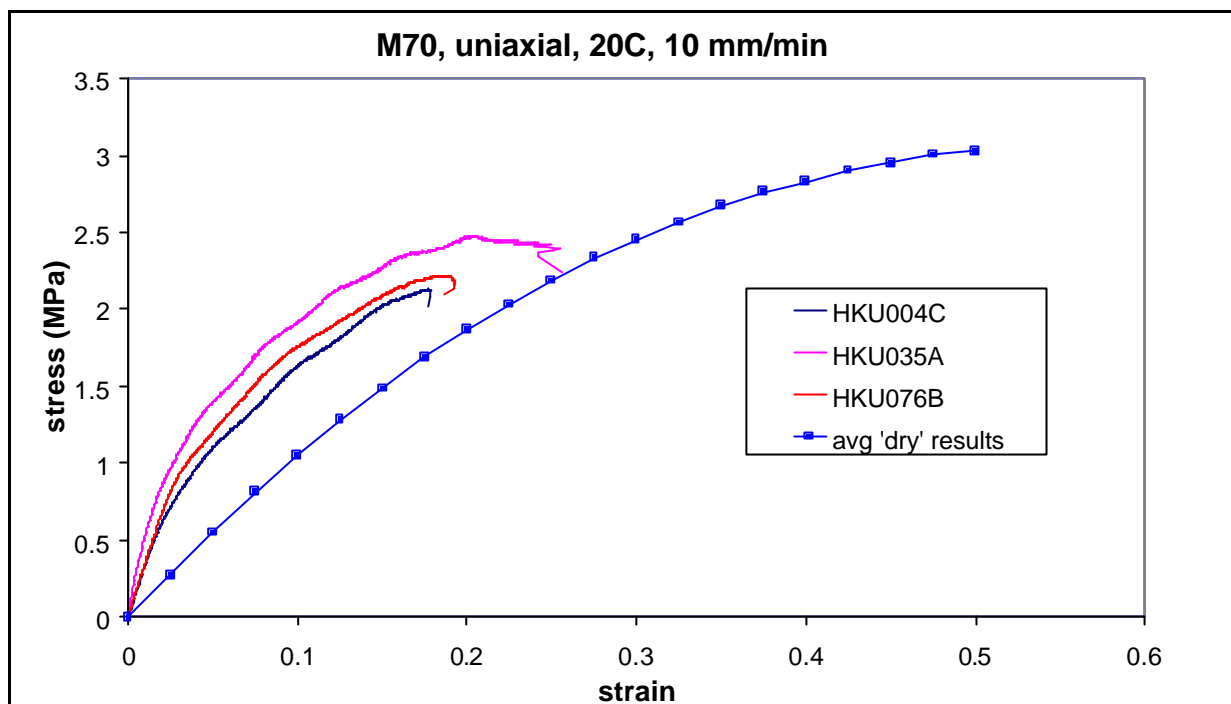


Figure A3: Tensile tests at 20 °C and 10 mm min⁻¹ (rate = 3x10⁻³ s⁻¹)

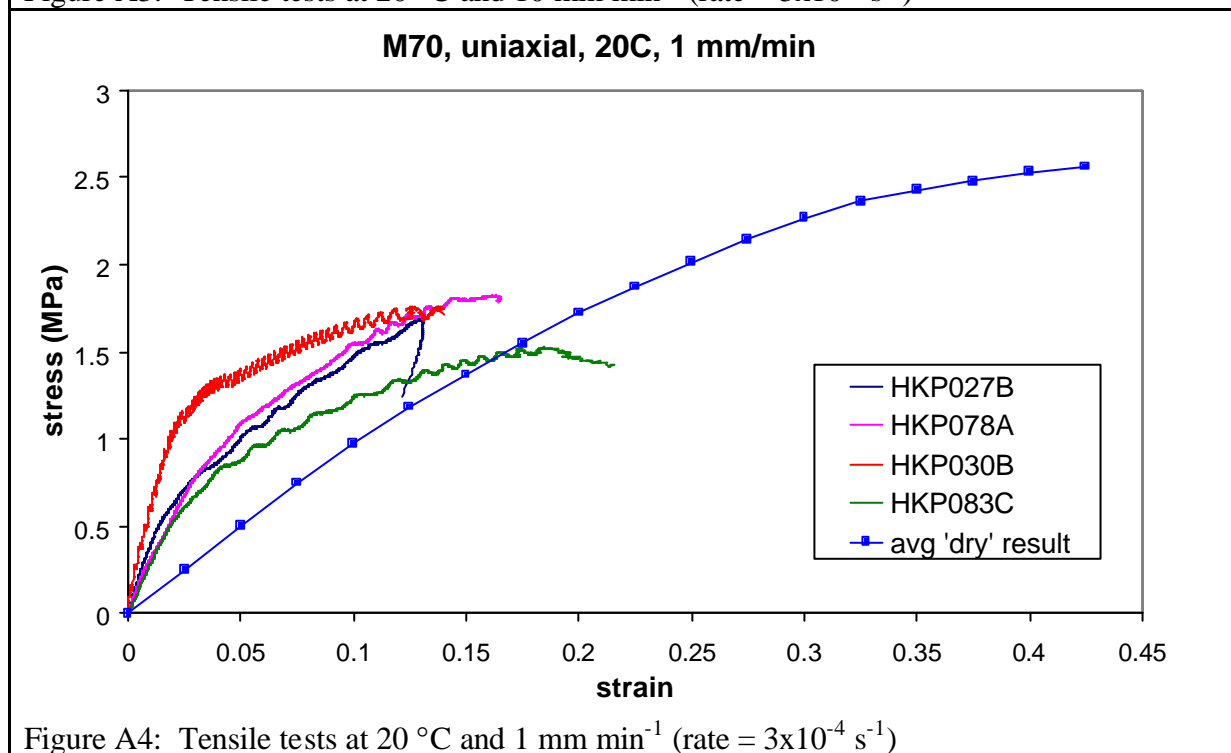
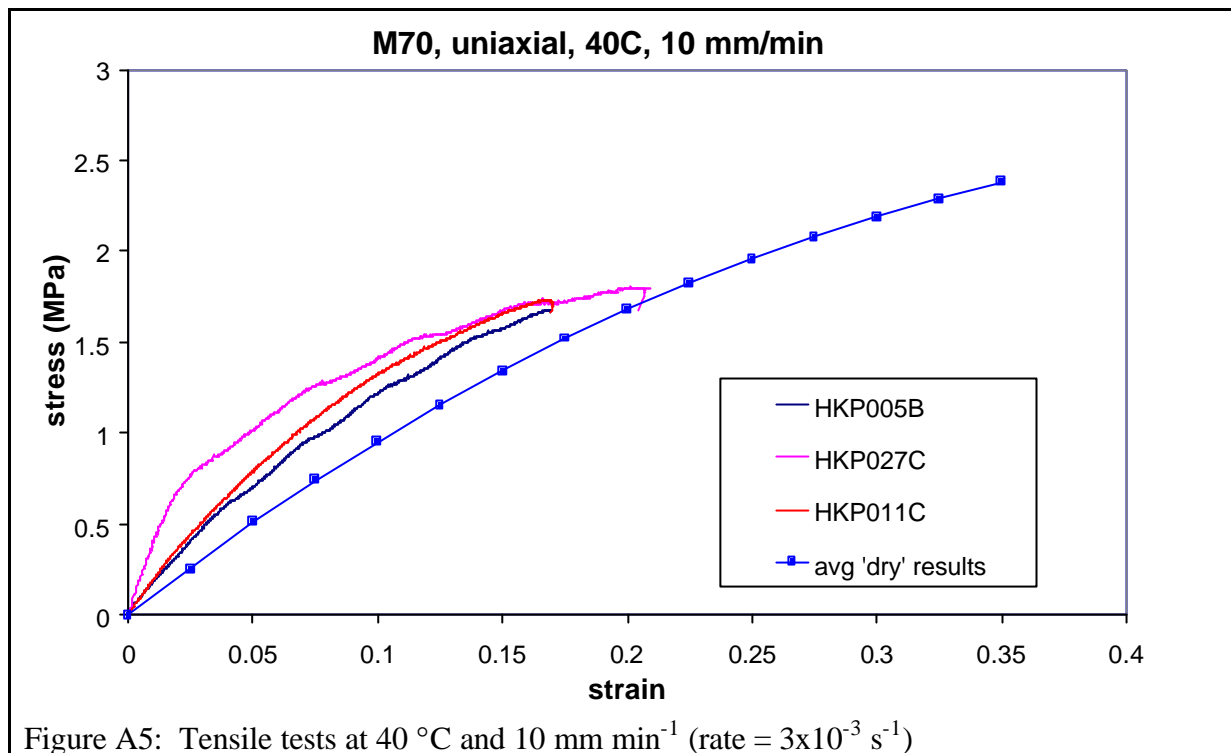


Figure A4: Tensile tests at 20 °C and 1 mm min⁻¹ (rate = 3x10⁻⁴ s⁻¹)



Temp °C	Rate s ⁻¹	Axial strain	Stress (MPa)	Lateral strain	Poisson's ratio	True strain	True stress (MPa)
0	3.04E-03	0.269	3.25	0.0294	0.11	0.214	3.45
20	3.55E-02	0.308	2.92	0.0436	0.15	0.268	3.18
20	3.00E-03	0.209	2.27	0.0309	0.16	0.189	2.42
20	3.39E-04	0.157	1.70	0.0246	0.16	0.151	1.78
40	2.93E-03	0.183	1.74	0.0451	0.26	0.168	1.91

Table A1: Properties of exposed M70 tensile specimens.

Temp °C	Rate s ⁻¹	Axial strain	Stress (MPa)	Poisson's ratio	Lateral strain	True strain	True stress (MPa)
0	3.00E-04	0.422	3.12	0.27	0.114	0.352	3.974
0	3.00E-03	0.468	3.87	0.26	0.122	0.384	5.017
0	3.00E-02	0.491	5.51	0.25	0.123	0.399	7.160
0	8.00E-02	0.34	5.01	0.28	0.095	0.293	6.120
20	3.00E-04	0.39	2.19	0.3	0.117	0.329	2.809
20	3.00E-03	0.487	2.87	0.29	0.141	0.397	3.892
20	3.00E-02	0.484	3.5	0.26	0.126	0.395	4.580
20	8.00E-02	0.42	3.79	0.26	0.109	0.351	4.776
40	3.00E-04	0.289	1.92	0.3	0.087	0.254	2.302
40	3.00E-03	0.344	2.26	0.31	0.107	0.296	2.832
40	3.00E-02	0.403	2.77	0.28	0.113	0.339	3.519
40	8.00E-02	0.353	2.87	0.29	0.102	0.302	3.562

Table A2: Properties of 'dry' M70 tensile specimens