Rail Embedment

Technical Specification

ALH Systems Limited

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HISTORY AND INTRODUCTION

In the early 1970's ALH Systems Limited developed resin systems for the encapsulation of underground gas pipes. In order for these encapsulation systems to be effective a number of unusual application and performance parameters had to be fulfilled. The resin system had to be applied to recently exposed cast iron pipe, bonding to that pipe in order to effect a seal against the internal gas pressure. The systems had to be capable of application on site by semi-skilled personnel in all climatic conditions of temperature and humidity.

Once installed the encapsulation system was buried and was required to resist flexing and vibration of the pipe in varying soil conditions for a considerable period of time without failure of the material or disbonding from the cast iron.

With the rapid developments of liquid polyurethane resins in the 1980's ALH Systems Limited produced their Series Six encapsulant system, which, when tested through an 18 month test programme, met all the requirements of the industry for an encapsulant capable of satisfactorily sealing in underground conditions with a life expectancy in excess of 50 years.

This material has now been in use for 13 years throughout the world with well over 1.5 million litres successfully applied.

Series Six has been utilised in other applications, for example, water sealing between concrete slabs, encapsulation of concrete pipe joints and, of course, rail embedment where long term resistance to the environment and flexibility are paramount.

SERIES SIX MATERIAL

This product is a two component modified polyurethane. The base component contains an amine as the reactive constituent blended with two highly chemical resistant extenders and a reinforcing inorganic filler. The hardener component contains a polyisocyanate prepolymer blended with a range of stabilisers. When mixed together in the correct stoichiometric ratio these two components will react to form a material with the following properties:

- high flexibility
- high resistance to abrasion and tear
- high resistance to water, dilute acids and alkalis and salt solutions
- non-foaming material due to the rapid reaction of amine and isocyanate and low water susceptibility of individual components
- high electrical resistance
- excellent vibration damping

SERIES SIX PRIMER

This product forms an integral part of the Series Six encapsulating system. It is based on a blend of urethane prepolymers, silane coupling agents and solvents. This primer can be used successfully on both porous substrates such as concrete and impervious substrates such as steel, cast iron and plastics, e.g. PVC, producing an excellent chemical bond between the substrate and the Series Six polyurethane elastomer.

SERIES SIX PHYSICAL PROPERTIES

TWO COMPONENT LIQUID MATERIAL

Colour:	Base material:	Black.	
	Hardener material:	Translucent and slightly straw coloured.	
	Mixed:	As base material.	
Viscosity @ 20°C:	Base material:	15 Poise	(Brookfield Viscometer
	Hardener material:	50 Poise	using No.3 spindle @ 10 rpm)
	Mixed material:	30 Poise	

Pot Life @ 20°C: 12 minutes standard but can be varied if required.

Mix Ratio (by weight): 2 parts Base : 3 parts Hardener.

Specific Gravity @ 20°C: 1.13

PROPERTIES OF CURED MATERIAL

IRHD Hardness @ 20°C:	60	
Tensile Strength:	4 N mm^{-2}	BS903:A2
Tear Strength:	19.5 N mm^{-1}	BS903:A3
Glass Transition Temp:	-46°C	
Electrical Resistance of:	$>2 \times 10^8\ \Omega$	Test piece of surface area 12.5 cm^2 and width 1 cm
Water Absorption:	0.5%	12 months total immersion on 6mm thick sample
Young's Modulus:	2.56 MN m^{-2}	Based on samples tested @ 23°C at a strain rate of 12mm per minute after curing for 72 hours @ 23°C.
Poisson's Ratio:	0.4996	
Coefficient of Expansion:	34×10^{-5} °C^{-1}	
Shear Modulus:	0.68 MN m^{-2}	Based on samples tested @ 23°C at a strain rate of 12mm per minute after curing for 72 hours @ 23°C.

SERIES SIX ADDITIONAL PROPERTIES

1. ACCELERATED UNDER BOND CORROSION TESTING

Test:

Samples of Series Six bonded to metal plates were produced with exposed unprotected metal either side of the polymer. These samples were immersed in a salt solution and a current of 15×10^{-3} mA mm^{-2} applied for 9 weeks.

Result:

On removal of the Series Six polymer no underbond corrosion was evident. This test simulates a 50 year in ground corrosion test.

2. THE EFFECT OF ADDED WATER ON SERIES SIX MATERIAL

Test:

Water was added to the base component of Series Six in the levels shown below. This was then mixed with the hardener component. Cleavage plate adhesion tests were conducted to assess the effect on the adhesive and mechanical properties of Series Six.

Result:

Water Added to base %	Load at Failure kN	Extension at Failure mm	Failure mode
0	4.13	36.3	Cohesive
0.5	3.82	39.0	Cohesive
1.0	3.45	42.9	Cohesive
3.0	3.38	44.1	Cohesive
5.0	2.43	45.6	Cohesive

Series Six does not foam in the presence of water, the addition of which acts as a non-reactive dilutant i.e. it reduces the load and increases the extension at break.

3. THE EFFECT OF TEMPERATURE ON LIQUID COMPONENTS/MIXING

Low temperatures (to -5°C)

As the temperature reduces, the viscosity of both the base and hardener component increases. The material will be more difficult to mix and pour, flow under the foot of the rail and will be slower to cure than at temperatures of 10°C or above. It is advisable to store materials in a warm place (10° to 25°C) during cold weather.
Although gel times will increase and the rate of cross-linking will be slower than at higher temperatures, there is no detrimental effect on the final mechanical properties.

High temperatures (to 30°C)

As the temperature increases the gel time will decrease. The material should be mixed and poured quickly.
Note: The standard gel time is 12 minutes @ 23°C; this can be modified if required.

4. *TENSILE & TEAR STRENGTH PROPERTIES OF SERIES SIX*

Tensile Strength

(a) Variation in stress and strain with increase in strain rate at 23°C to BS903:A2 - Dumb bells

Strain Rate $mm\ min^{-1}$	Stress $N\ mm^{-2}$	Strain %
1	3.08	278
10	3.79	294
100	4.93	314

(b) Variation in stress and strain with increase in temperature at 100mm per minute strain rate.

Temperature °C	Stress $N\ mm^{-2}$	Strain %
0	8.34	387
30	4.48	272

(c) Variation in stress and strain with increase in cure time.

Cure time	Stress $N\ mm^{-2}$	Strain %
3 hours	2.86	621
1 day	4.24	388
2 days	4.63	371
7 days	4.99	333
14 days	4.69	308
21 days	4.89	299

Tear Resistance

Notched crescent samples to BS903:A3

Temperature °C	Strain rate $mm\ min^{-1}$	Tear strength $N\ mm^{-1}$
23	1	15.2
23	10	19.6
23	100	21.3
23	1000	22.2
-10	10	15.7
0	10	18.5
30°C	10	27.5

5. *ENVIRONMENTAL PERFORMANCE OF SERIES SIX*

Method:

Test samples were immersed in the various fluids and were then tested after 4, 8 and 12 months immersion. The samples were pulled to failure and the strength of the material measured.

Test Environments:

a) Air (control)
b) Tap water
c) 1% sodium chloride solution (wt/wt)
d) 1% sodium sulphate solution (wt/wt)
e) pH 8.5 buffer solution
f) pH 4.5 buffer solution
g) Monoethylene glycol (liquid)
h) ICI 'Weasel', a mixture of low boiling point aliphatic alcohol and diethylene glycol (liquid)
i) Shell, Carnea 21 mineral oil (liquid)
j) Shell distillate, complex mixture of hydrocarbons (50% saturated vapour)

Results:

Test Environment	Adhesion Test		Exposure Period		
			4 months	8 months	12 months
Air	Load	kN	3.63	3.34	4.00
	Extension	mm	8.10	6.75	8.70
Tap Water	Load	kN	3.59	3.36	3.33
	Extension	mm	13.60	11.75	15.80
1% Na Cl	Load	kN	4.05	3.32	3.70
	Extension	mm	15.80	12.25	12.70
1% Na_2 SO_4	Load	kN	3.36	3.40	3.53
	Extension	mm	10.30	12.00	11.59
pH 8.5	Load	kN	3.57	3.45	3.75
(Alkali)	Extension	mm	11.35	11.75	11.70
pH 4.5	Load	kN	3.47	3.12	3.59
(Acidic)	Extension	mm	8.80	10.66	11.90
MEG	Load	kN	3.10	3.10	3.91
	Extension	mm	8.97	6.32	9.73
WEASEL	Load	kN	3.73	3.83	3.29
	Extension	mm	8.78	8.38	7.50
SHELL	Load	kN	4.31	4.20	3.98
CARNEA 21	Extension	mm	10.80	9.31	9.76
SHELL	Load	kN	4.15	4.16	3.64
DISTILLATE	Extension	mm	9.95	9.60	8.04

Air at 0 months	Initial Test	Load	3.11	kN
	(7 Days Cure)	Extension	8.90	mm

SERIES SIX RAIL EMBEDMENT PROPERTIES

1. ELECTRICAL RESISTANCE

Method:

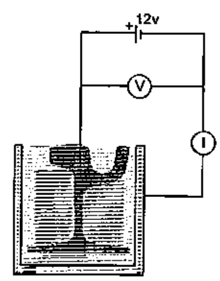
Samples were produced by pouring and bonding Series Six between two metal plates each 50mm x 25mm and spaced 10mm apart. After 72 hours the electrical resistance at 200 volts was measured. Samples were also immersed in water for a period of 7 days, surface water was removed and the electrical resistance measured.

Results:

Material	Resistance Dry Ω	Resistance Wet Ω
Series 6 (no additional filler)	2000×10^6	660×10^6
Series 6 (Cork filled)	2000×10^6	660×10^6
Series 6 (Bauxite filled)	2000×10^6	1000×10^6
Competitor's Material	20×10^6	17×10^6

In both the wet and dry states Series Six is classed as an electrical insulator as it has a resistance greater than 10^8 Ω.

Method:



A section of rail 500mm long was embedded within a metal trough using Series Six Rail Embedment polyurethane elastomer. The electrical resistance between the rail and the surface of the embedding material in contact with the trough was calculated using the formula.

$$R = 25 \times 10^{-5} \frac{V}{I} \quad \Omega\,\text{km}$$

Results:

1000 single track Ω km.
Series Six is an excellent insulator.

2. SKID RESISTANCE

Introduction:

The skid resistance of Series Six was carried out using a Stanley/TRRL Portable Skid Resistance Tester. This device measures the coefficient of friction between a patterned tyre skidding at 30mph and a road surface.

Method:

The test device consists of a pendulum, attached to which is a sample of "standard" tyre tread rubber mounted on a spring loaded slider. The pendulum height is adjusted to give a contact surface area length of 5 inches.
The pendulum is released and rubber surface of the slider passes over the test surface thereby slowing down the motion. The higher the friction forces the less distance the pendulum will travel. The distance travelled is recorded directly onto a scale in units of skid resistance (0-150, the higher the figure the higher the skid resistance).

Results:

Substrate	Dry	Wet
Concrete	102	52
Steel	64	19
ALH Series Six	117	24
Competitor's material	93	23
ALH + Bauxite Anti-skid	108	88
ALH + Flint	94	60
ALH + Granite (14mm,68PSV)	93	62

Conclusions:

Polyurethanes in the wet, like steel, have poor skid resistance. By the incorporation of an antiskid surface coating to the polyurethane the skid resistance is dramatically improved.

3. ABRASION RESISTANCE

Introduction:

The abrasion resistance of Series Six was measured using a Teledyne Taber Model 503 Abrasion Tester. This equipment measures the abrasion resistance of materials in terms of weight loss over a set number of cycles using standard abrasive wheels.

Results:

Material	Abrasive Wheels	No. of Cycles	Average Weight Loss grams
ALH Series Six (Cork filled)	CS 17	1000	0.08
Competitor	CS 17	1000	0.49
ALH Series Six (Cork filled)	H 18	1000	0.61
Competitor	H 18	1000	1.24
ALH Series Six (Bauxite filled)	H 18	1000	0.15
Competitor (Bauxite filled)	H 18	1000	1.09
ALH Series Six (Bauxite filled) plus bauxite surface dressing	H 18	1000	Test aborted after Run 1 due to dressing erosion of test wheel but no weight loss to sample.

CS 17 is a soft wheel   H 18 is a very coarse wheel

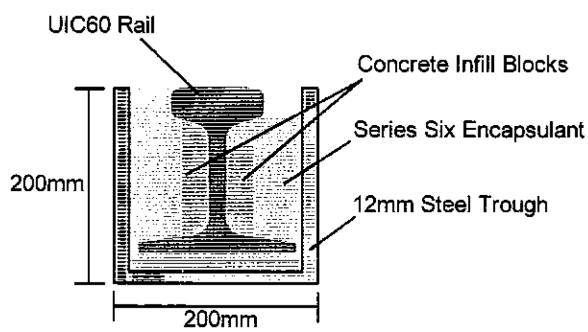
Conclusions:

In all tests Series Six proved to be excellent in terms of abrasion resistance.

4. LOAD DEFLECTION CHARACTERISTICS

Introduction:

A 650mm long section of UIC60 rail was embedded in a steel trough. The rail was then subjected to vertical loadings at various temperatures and the vertical deflection recorded.

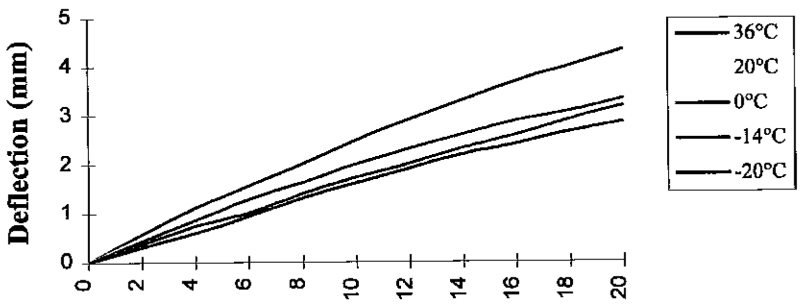


Trough and Rail Length: 650mm

Results:

A graph showing the results is given below.

Graph showing the deflection of a section of UIC 60 tram rail loaded at different temperatures



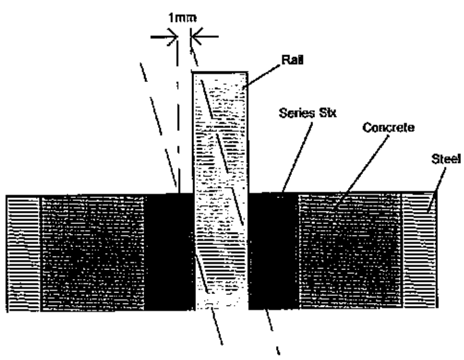
Load (Tonnes)

5. VIBRATION TESTING

Introduction:

a) A steel bar, representing the rail was embedded using Series Six within a concrete and steel tube.

The "rail" was deflected such that the movement at the rail/Series Six interface was 1mm.
The frequency of cycling was set at 3Hz and the test at room temperature ran for 82 days continuously.



Results:

(a) 20.5 million cycles were completed with no sign of distress.

- There was no disbondment between the encapsulant and concrete.
- There was no disbondment between the encapsulant and metal "rail".
- There was no tearing or splitting of the encapsulant at or around small holes caused by air bubbles present on the surface.
- There was no change in the hardness of the encapsulant during the test period.
- There was no increase in the temperature of the encapsulant during the test (hysteresis).

(b) Site testing.

Vibration measurements were carried out by BR Research as follows.

BR RESEARCH

VIBRATION MEASUREMENT ON ALH EMBEDDED- RAIL TRACK

SHEFFIELD, AUGUST 1996

Measurements of the wayside vibration from street running, in-service SuperTrams have been taken, at the request of ALH, in Middlewood Lane, Sheffield on the morning of the 29th August 1996. The measurement positions were 1 metre from the nearest rail of the inbound tram track. At this location this meant that the transducers were positioned on the tarmac near to the gutter. There is an incline at this site and the inbound (towards Sheffield) trams were travelling uphill past the measurement positions. In order to reduce the effect of other road traffic (causing additional vibration or congestion), the measurements were taken early in the morning.

The vibration was measured in three directions, using piezo-electric accelerometers. A B&K sound level meter (type 2231) with a vibration module (type 2252) was used to measure the peak particle velocities. The instrumentation was calibrated before and after use.

Two measurement positions were used:

Position 1 — opposite OHL equipment mast number 2262. Adjacent to the track with an anti-skid layer on the surface of the ALH embedded-rail material

Position 2 — approx. 17 metres from OHL mast number 2263 towards 2264. Adjacent to the track without the anti-skid layer.

The approximate speed of the trams was determined by timing their passage.

Measurement position	Vehicle	Approx. speed (km/h)	Peak particle velocity (mm/s)		
			Vertical	Transverse	Longitudinal
1 (anti-skid)	SuperTram	-	1.15	0.37	0.36
	SuperTram	40	0.98	0.47	0.32
	SuperTram	35	0.89	0.39	0.24
2 (no anti-skid)	SuperTram	34	1.31	0.40	0.29
	SuperTram	43	1.36	1.14	0.62
	SuperTram	47	1.09	0.33	0.25

JRB QD/85226/VIBM

30 August 1996