Compressive strength testing of Hahn Plastics Ltd biofilter leg components exposed to concentrated acid

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Leeds Sustainability Institute

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Executive summary

Twelve tenon-crowned leg components from Hahn Plastics Ltd's biofilter floor system were subjected to compressive strength testing in order to investigate if their performance was affected by twelve weeks of exposure to extremely-low pH acid solutions.

Of the twelve leg samples, four samples were not exposed to any acidic solutions in order to provide control samples. A further four samples were immersed during the twelve weeks in a pool of acid solution, while a final four samples were sprayed twice-daily for twelve weeks with acid solution in order to create streaks that would run down the sides of the legs, forming slight pooling at the bottom.

Upon completion of the twelve week period, all twelve samples were subjected to identical compressive strength testing in a Denison loading frame, in accordance with the methodologies stipulated in BS EN ISO 604:1997.

Main findings

Compressive strength testing showed that samples exposed to extremely-low pH acid solutions presented no reduction in the performance of the leg components when compared to the control samples not exposed to extremely-low pH acid solutions.

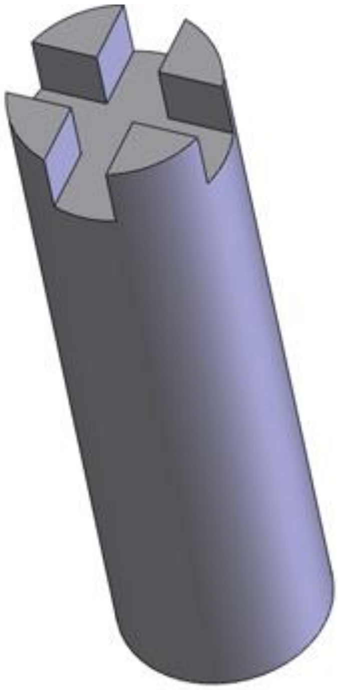

Figure 1 Hahn Plastics Ltd tenon-crowned leg component.

1. Introduction

Leeds Sustainability Institute (LSI) have been requested to provide materials testing of the leg components belonging to the Hahn Plastics Ltd biofilter floor system. The nature of this testing was to establish if there was any reduction in the compressive strength of the legs after they have been exposed to extremely low pH solutions.

1.1. Investigative rationale

Figure 1.1 shows the typical configuration of the biofilter floor system, as it is being installed onto a concrete base foundation, including the floor grids that are located on top of the tenon-crowned leg components so as to create a plenum (a chamber designed to hold gases at positive pressure) below an organic filter bed that sits upon the floor grids. During the operation of the biofilter, the action of the microbial agents within the humid conditions of the filter bed produces volatile organic compounds (VOCs), including sulfuric acid compounds such as Hydrogen Sulfide (H_2S). Water vapour condensations containing these VOCs trickle down through the filter bed and onto the surfaces of the load-supporting leg components below, finally pooling where the legs meet the foundation base. This exposes the legs to contact with solutions of low pH during normal operations.

The rational of the investigation was to simulate continual exposure of the leg components used in the Hahn Plastics Ltd biofilter floor system to extremely-low pH soluble sulfuric acid, prior to compressive strength testing that was use to establish if there was any quantitative reduction in their load-bearing performance.

Figure 1-1 Hahn Plastics Ltd biofilter floor system at Montepellier, France.

2. Materials and methodology

2.1. Materials

LSI requested, and received, twelve tenon-crowned leg component samples all sourced from the same batch of production from Hahn Plastics Ltd. Hahn Plastics Ltd were not made aware at any stage as to which samples were to be selected for the three various test cells that will now be described below.

2.1.1. Preparation of materials in three different test cells

In order to meet the requirements of the investigative rationale discussed in 1.1, the twelve samples were sub-divided into three test cells:

- 4 x control samples

Control samples were randomly selected to be stored in a cool, dry environment for a twelve-week period, prior to compressive strength testing.

- 4 x pooled samples

Pooled samples were randomly selected to be immersed in a solution of sulfuric acid (H_2SO_4) maintained at a pH of 1 – 1.5 for a twelve-week period, prior to compressive strength testing. The depth of immersion was maintained at 150 mm, representing 20% of the total length of the sample, a value far in excess of expected acidic pooling during normal operation.

- 4 x streaked samples

Streaked samples were randomly selected to be sprayed twice-daily with a solution of sulfuric acid (H_2SO_4) maintained at a pH of <1 for a twelve-week period, prior to compressive strength testing. The solution was sprayed to the top 100 mm of each sample until heavy beading and streaks had formed and were flowing down around the whole exterior surface, representing acidic condensations formed during normal operation.

Upon completion of the twelve weeks of extremely-low pH exposure periods, the pooled and streaked legs were washed of the acid solution prior to compressive strength testing.

2.2. Methodology

Samples were subjected to axial compressive loading of up to 100 kN using a Denison loading frame, following BS EN ISO 604:1997. The loading was applied incrementally in five loading stages; 20, 40, 60, 80, 100 kN, and the associated failure criteria during loading phases are discussed in 3.1.

BS EN ISO 604:1997 requires that samples have a length to diameter ratio of 2:1. The legs were tested in their operational configuration, leading to a ratio of 5:1. As testing simply represents an internally comparative investigation, this conscious departure from BS EN 604:1997 does not represent a concern to the outcomes of the tests.

3. Results

3.1. Failure criteria

Section 3 of BS EN ISO 604:1997 states that sample compression should continue until one of two criteria is met; the recorded axial loading (*P*) reduces by a predetermined value, or the change in length (Δ*L*) of the sample exceeds a predetermined value. For all of the loading phases, the following values represented the above failure criteria:

- *P* reduces by 10% at any point after an applied loading increment.
- Δ*L* exceeds 50 mm in under 1 minute of an applied loading increment.

3.2. Calculations

At all stages of the compressive strength test, the loading frame software recorded the values of *P* and Δ*L*. From this telemetry and measurements of each sample's length (*L*) and cross-sectional area (*A*), the values of axial strain (ε) and compressive stress (*σ*) were calculated using Equations 3.1 and 3.2 respectively:

$$\varepsilon = \frac{\Delta L}{L}\, x\, 100 \qquad \text{Eq 3.1}$$

$$\sigma = \frac{P}{A} \qquad \text{Eq 3.2}$$

3.3. Test data

Table 3.1 shows the values of *P* for all samples at 5 mm intervals of Δ*L*, and the value of ε represented. The maximum values of σ recorded (σ_M) during each test is shown at the bottom. Figure 3.1 graphically depicts the *P v* Δ*L* data recorded during each test for all of the control, pooled and streaked samples.

Table 3-1 Recorded test data for all samples.

Δ*L* (mm)	ε (%)	*P* (kN)											
		Control sample				Pooled sample				Streaked sample			
		1	2	3	4	1	2	3	4	1	2	3	4
5	0.6	27.2	23.8	20.9	25.3	23.7	23.2	22.9	24.9	26.3	23.6	24.7	22.8
10	1.3	51.0	46.2	44.5	48.9	45.4	44.3	45.9	47.1	47.4	44.1	47.6	44.1
15	2	67.3	60.1	60.1	62.7	61.7	60.2	60.3	60.6	62.1	60.2	63.0	60.1
20	2.6	80.1	75.4	74.6	79.3	77.8	74.4	74.6	76.9	77.6	74.5	79.5	75.2
25	3.3	91.7	80.1	83.4	87.5	86.4	80.1	81.1	84.4	84.3	81.3	89.0	82.8
30	4	100.0	91.5	93.6	95.8	96.3	92.1	89.1	93.6	92.5	90.2	98.6	92.8
35	4.6	99.9	99.3	100.0	100.2	100.2	99.2	96.3	99.0	99.7	96.6	100.1	99.5
40	5.3	99.9	100.1	100.0	100.1	100.0	99.6	99.8	99.8	100.0	99.9	99.9	100.0
45	6	99.8	100.1	99.9	99.9	100.0	100.1	99.9	99.8	99.9	100.0	99.9	99.9
50	6.6	99.8	99.9	99.8	99.8	99.9	99.9	99.6	99.5	99.7	99.8	99.8	99.7
σ_M (x 10^{-2} MPa)		1.019	1.019	1.020	1.020	1.020	1.019	1.018	1.017	1.019	1.019	1.019	1.019

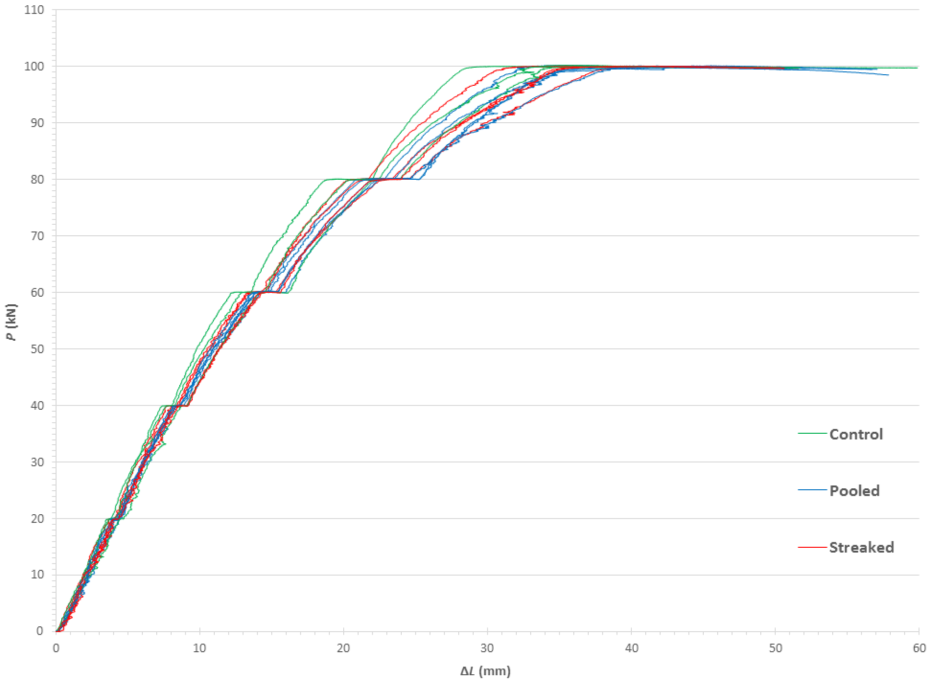

Figure 3-2 Data plot of P v ΔL for all control, pooled and streaked samples.

The data covered in Figure 3.1 has been averaged in Figure 3.2, so as to show a clearer pattern as to how the compressive strength of samples compared, depending on how they were prepared according to 2.1.1. Figure 3.3 shows this averaged data converted into a *σ v* ε relationship.

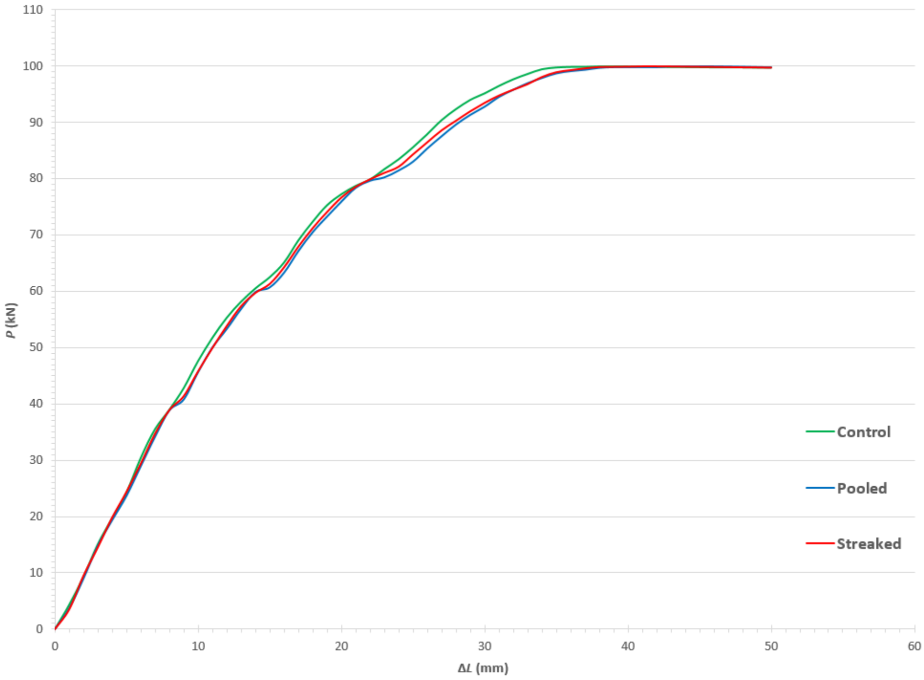

Figure 3-2 Averaged plot of P v ΔL for all control, pooled and streaked samples.

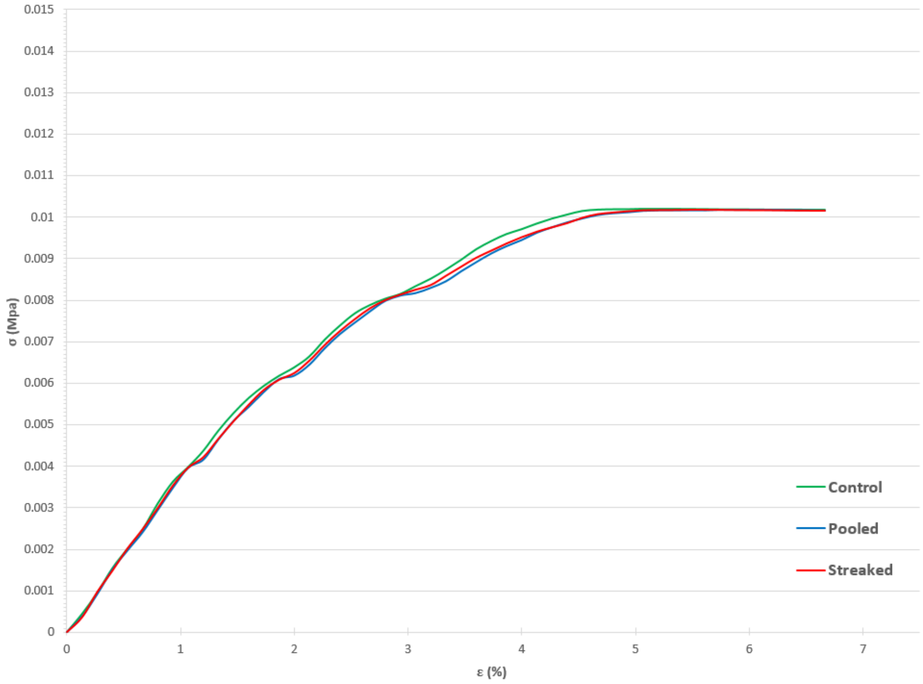

Figure 3-3 Averaged plot of σ v ε for all control, pooled and streaked samples.

4. Discussion

Examination of Table 3.1 reveals the consistency of all samples to resist compressive loading, regardless of whether they were from the control, pooled or streaked test cells. At least one sample from all three test cells resisted up to ≥ 100 kN by 35 mm of ΔL. Of the three samples that displayed the highest σ_M value of 1.020×10^{-2} MPa, two were controls and one was a pooled sample. The remaining samples were between the values of 1.019×10^{-2} and 1.017×10^{-2} MPa. The consistency of the compressive strength of all the samples was further demonstrated by the curves produced from the test data, including P v ΔL Figures 3.1 and 3.2, and σ v ε Figure 3.3. No discernible quantitative difference in any table or curve can be seen that might suggest that there is any evidence of the reduction in the expected performance of the non-control samples, post-exposure to the extremely-low pH solutions of H_2SO_4.

5. Summary conclusion

The investigation conducted by LSI, of Leeds Beckett University, has found no evidence that the compressive strength performance of Hahn Plastics Ltd's tenon-crowned leg components of the biofilter floor system has been affected by the twelve-week exposure to extremely-low pH solutions of sulfuric acid.

6. Reference to standards

BSi (1997) BS EN ISO 604:1997 – Plastics – Determination of compressive properties. British Standards Institute, Milton Keyens.