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Report on: Fatigue and Dynamic Stiffness Testing of Rolled Asphalt with Chemcrete Binder

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Introduction

Chemcrete is a bitumen with a chemical additive which, during the course of a curing period, increases its stiffness. Tarmac had performed a preliminary investigation into the influence of Chemcrete in a rolled asphalt wearing course mix on Marshall stability values under various curing temperatures and periods. These results indicated substantial increases in stability showing the material to have promising potential for minimising rutting in rolled asphalt wearing courses on heavily trafficked roads.

The University was asked to extend this investigation by using their repeated load apparatus to examine both the dynamic stiffness and the fatigue cracking resistance of rolled asphalt made with Chemcrete.

Dynamic stiffness is the ratio of stress to strain under repeated load conditions representative of those experienced in the road under moving traffic. It provides a measure of the load spreading ability of the layer.

Fatigue cracking of bituminous materials is a well known phenomenon which has been the subject of extensive research both at Nottingham and by a number of other research organisations. This work has all indicated that bituminous materials will crack under repeated applications of tensile stress (and strain) and such cracking clearly weakens the in situ layer.

The general approach to this investigation involved the performance of comparative tests on a standard rolled asphalt wearing course mix and the same mix incorporating Chemcrete.

All the materials were supplied by Tarmac and specimens were manufactured at Nottingham. Identical Marshall specimens were prepared by Tarmac to monitor the gain in stability as curing proceeded. The Nottingham specimens were cured in an identical way and tested when advised by Tarmac that their stability results had reached an appropriate level.

Specimen Preparation

The specimens were 100 mm in diameter and 200 mm long. Table 1 shows the blend used to manufacture one specimen, the stone being weighed out in a tray, pre-heated in an oven and then mixed with the bitumen or Chemcrete in a heated mixer. The binder was maintained at 150°C but in the case of the Chemcrete smaller quantities were heated and used as soon as possible in order to limit the time this binder was at an elevated temperature.

The hot mix was then placed in four layers in preheated moulds, each layer being tamped 25 times with a hot poker, to distribute the material and expel air. Each end of the specimen was then subjected to 50 hammer blows using an automatic compactor. On cooling, the specimens were extruded and air voids measured; Table 2. These were lower for the Chemcrete specimens (4.6% average) compared with the conventional ones (5.2% average).

Table 1 Constituent Material Details

Material	Blend	Specific Gravity	Weight (gm)
Gritstone coarse agg.	30%	2.79	1200
sand	53.2%	2.63	2128
filler	9.2%	2.87	368
50 pen Bitumen or Chemcrete	7.6%	1.03	304

Table 2 Percentage Air Voids

Specimen No.	Voids	Specimen No.	Voids
50/1 Conventional	5.2	C1 Chemcrete	4.8
50/2	5.3	C2	4.7
50/3	5.0	C3	4.7
50/4	5.3	C4	4.5
50/5	4.9	C5	4.7
50/6	5.3	C6	4.9
50/7	5.1	C7	4.3
50/8	5.2	C8	4.8
50/9	5.3	C9	4.6
*50/10	5.1	C10	4.4
*50/11	5.2	C11	4.6
*50/12	5.1	C12	4.9
50/13	5.3	C13	4.7
50/14	5.3	C14	4.2
50/15	5.0	C15	4.5
Average =	5.2	C16	4.4
		C17	4.2
		C18	5.3
		C19	4.4
		C20	4.7
		C21	
		Average =	4.6

*Placed in oven with Chemcrete specimens.

Hence the lower viscosity of the Chemcrete at 150°C improved compaction. Once extruded from the moulds the Chemcrete specimens were stored in trays of sand in an oven at 45°C for six weeks when Tarmac advised that testing should start. In order to prevent further curing, the Chemcrete specimens were placed in a cold room at 10°C. Three of the conventional specimens were also stored in the same manner as some slight hardening of the 50 pen binder may occur with a subsequent effect on the dynamic stiffness and fatigue performance. The other 50 pen mixes were immediately stored in the cold room after manufacture.

Testing Procedure

Each specimen was glued to a pair of recessed circular end caps. Small diameter pairs of threaded brass targets were bonded at 100 mm vertical spacings on opposite sides of the specimen to be tested and displacement transducers were attached to these so that vertical strain could be determined. This assembly was bolted to the base flange and moving ram flange of a servo controlled hydraulic testing machine and the specimen was brought up to temperature (20°C) within an environmental cabinet. The arrangement is shown in Fig. 1, though the photograph shows a cored specimen rather than a moulded one. Short duration sinusoidal load increments were then applied at 16.7 Hz (corresponding to a vehicle speed on the road of about 100 km/hr) and the central vertical displacement was monitored on an Ultra Violet recorder. Tensile stresses in the range 500 to 2,000 kPa were applied during these short bursts of loading. From a knowledge of the specimen cross-sectional area and transducer gauge length, axial stress and strain were calculated at each increment.

A strain level was chosen from these results and the relevant load applied to proceed with the fatigue test. This load was maintained by the servo system until specimen failure occurred, at which point the power was automatically cut off and the machine stopped. The number of cycles was recorded by a counter. The load took the form of a sinusoidal tension compression cycle about a slightly compressive mean which restricted the tendancy for permanent tensile deformations to develop. However, the failure mode was tensile and began as a crack near the end fixing, which rapidly propagated and caused complete failure. It is more satisfactory to obtain a failure at mid-height of the specimen but this cannot always be guaranteed as a stress concentration occurs at the glue line around the flange recess. Previous experience has shown that the end failure does not affect the results.

Specimens with and without Chemcrete were tested at various strain levels to build up a strain-life relationship. The strain criterion was chosen as this parameter has been identified from previous research as the one which determines the initiation of a crack.

Results

Fig. 2 compares the strain-life relationships for the conventional rolled asphalt specimens with the Chemcrete ones. Inevitably in fatigue testing, there is considerable scatter of results. However, best fit lines have been drawn for each material and these indicate slightly poorer performance for the Chemcrete, i.e. shorter lives for the same strain. However, this must be considered in the light of the greater dynamic stiffness of Chemcrete as shown in Fig. 3. The Chemcrete mix is approximately twice as stiff as the conventional one and thus for the same stress a lower strain will develop in this material. The effect of this is illustrated in Fig. 4 which shows that for the same stress considerably longer lives would be obtained for the Chemcrete specimens. A proper comparison of the relative potential lives of these mixes in the pavement would require more detailed investigation using analytical techniques. The load induced strains could be computed for the respective stiffnesses and, using the fatigue data (Fig. 2), the relative lives established. However, this was not part of the present investigation.

For comparison, Fig. 5 shows fatigue curves for a range of conventional mixes predicted from the results of past research. It should be noted that the lives in Figs 2, 4 and 5 refer to laboratory conditions. Longer lives would be expected in the road. The steepness in the early part of the stiffness curves in Fig. 3 may be related in part to difficulties in measuring the very low deformations (and hence strains) in this stress region. However, the possibility that this is a real effect must also be considered.

There is a definite limit to the accuracy of the system ($\pm 5\times10^{-6}$ strain) and this may be reflected in the increased scatter and apparent downward trend for the Chemcrete specimens in Fig. 2 in the low strain area. The scatter is further emphasised by the expansion of the logarithmic scale for the strain levels in this region. At these long lives the tests take several days and, in some cases, were stopped (signified by an arrow) prior to failure.

With further reference to Figs 2 and 4, two of the conventional specimen results are circled. These are two of the three specimens which were kept in the oven for the same period as the Chemcrete ones. Although they are both below the strain-life fatigue line for the conventional material, they fall within the scatter band and did not therefore perform with any significant difference from the rest of the 50 pen specimens.

Conclusions

1. On the basis of tensile strain and for the particular rolled asphalt mix chosen, the Chemcrete specimens exhibited shorter lives.

2. If a stress criterion is used, then the fatigue performance of the Chemcrete mix is better than that of the conventional material.

3. The dynamic stiffness of the Chemcrete mix was approximately twice that of the conventional one. Consequently, a lower strain will develop in the former at the same stress.

4. Air voids were less for the Chemcrete specimens indicating improved compaction at the same temperature.

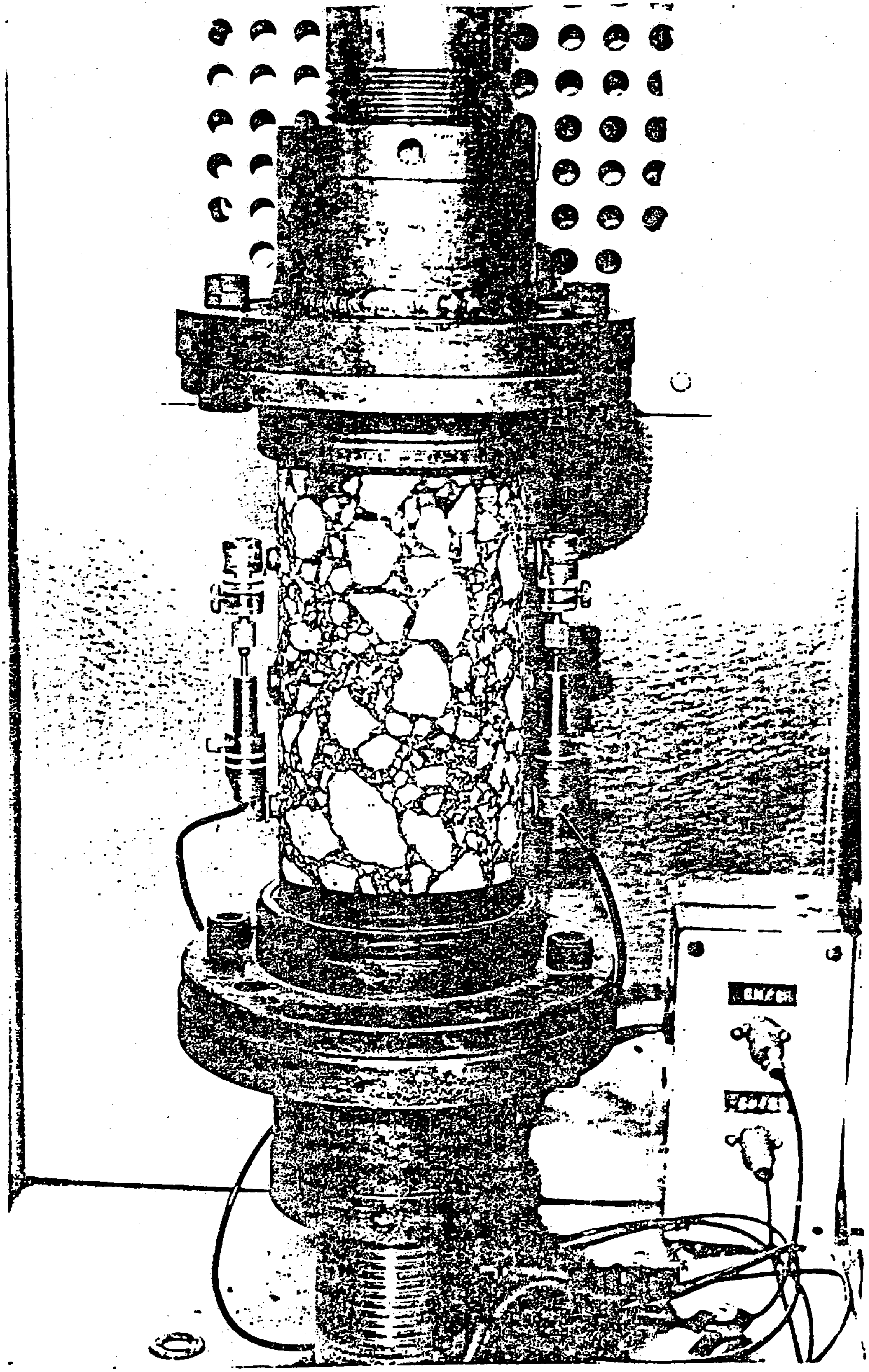


FIG. 1 ARRANGEMENT OF SPECIMEN FOR TESTING

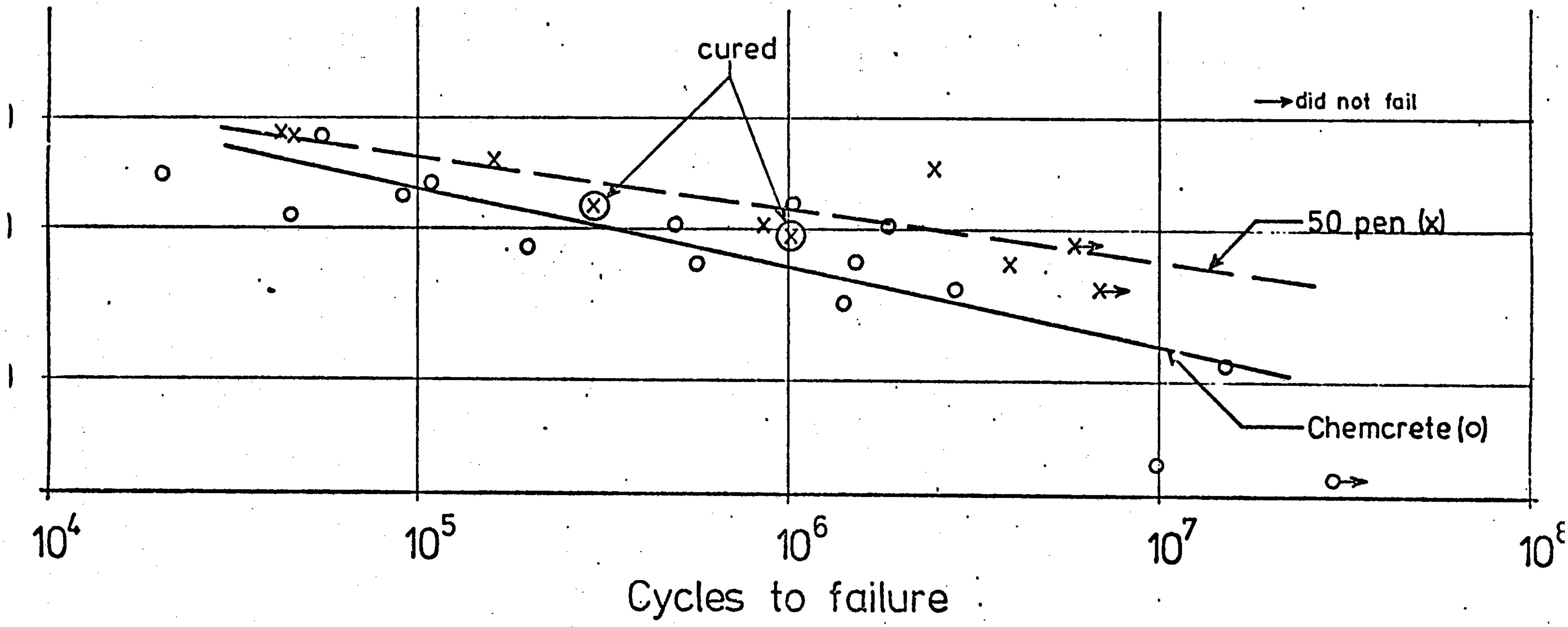


Fig. 2. STRAIN – LIFE RELATIONSHIPS.

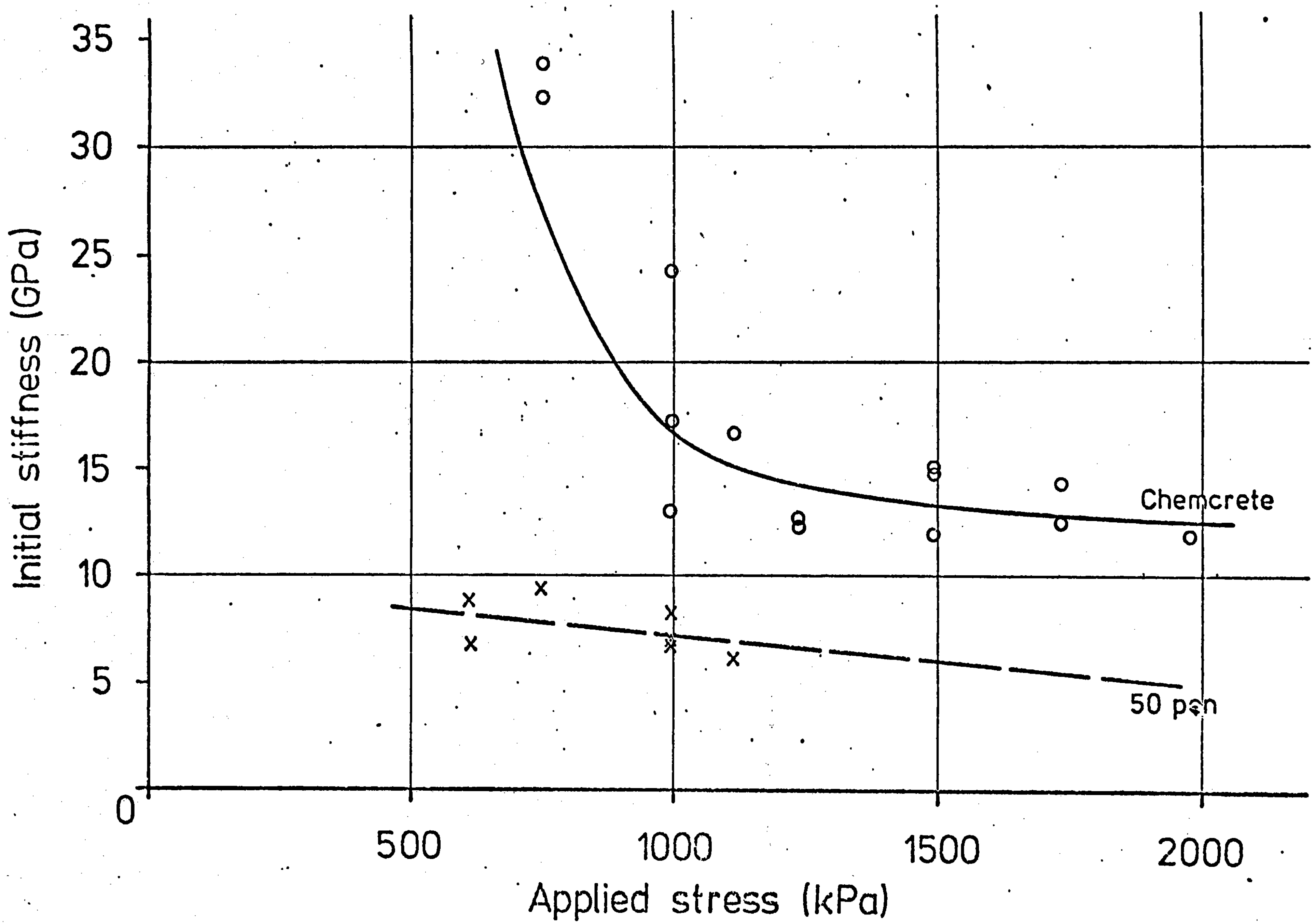


Fig. 3. INITIAL STIFFNESS AGAINST APPLIED STRESS.

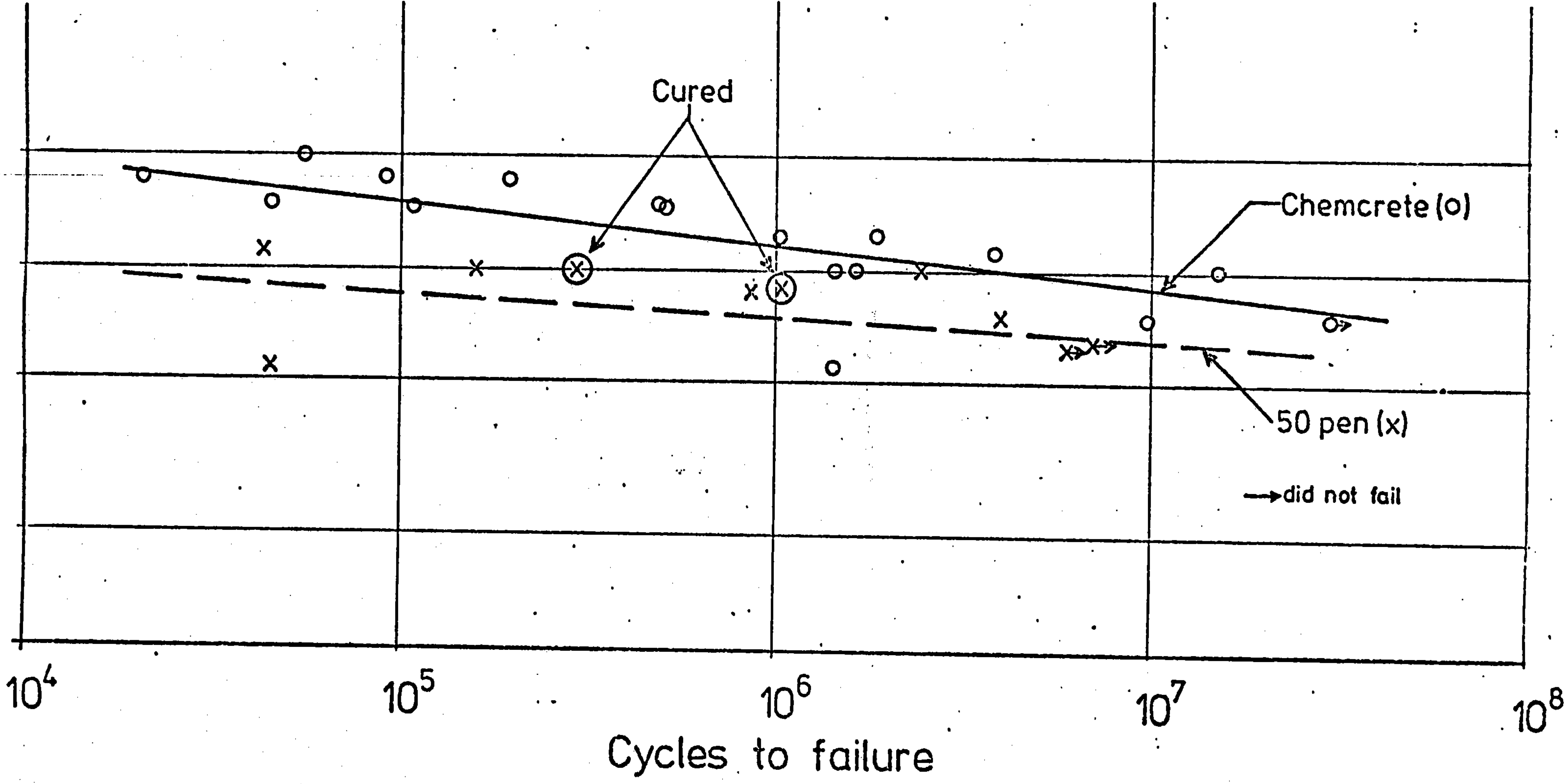
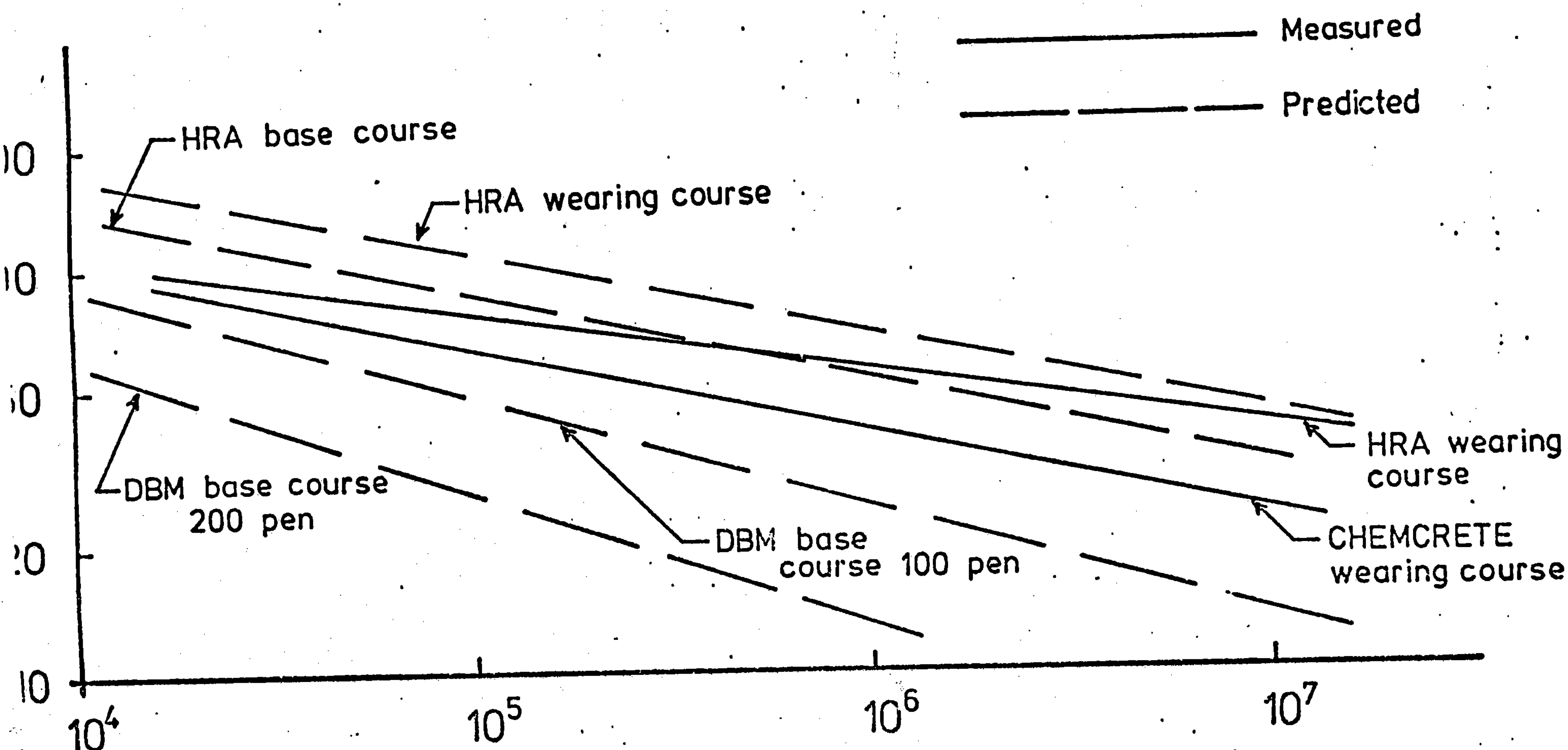


Fig. 4. STRESS-LIFE RELATIONSHIPS.

Measured
Predicted
HRA base course
HRA wearing course
HRA wearing course
DBM base course 200 pen
DBM base course 100 pen
CHEMCRETE wearing course
10
10
10
20
10
10^4
10^5
10^6
10^7
Cycles to failure