Block Tests

-Memorandum describing (repeated) two-block tests, proposal for inclusion in DPA TG1-

TG1, WP3, 4
benchmark of lifetime prediction methods

(revision 1)

Rogier Nijssen, January 2003

Introduction

Revision 0 of this document contained a proposal for the block tests and it was included in DPA of TG1.
Following the discussion in Stuttgart, 18/12/2002, this document contains a modified proposal for the block tests to be carried out in TG1. The most important change with respect to revision 0 is, that a proposal is made for possible elimination of tests if time is not available. Any comments are welcome!

Aim of block tests

The aim of the block tests in TG1 is to test residual strength degradation models, and to determine possible sequence effects and/or mutual influence of 'stress states'.

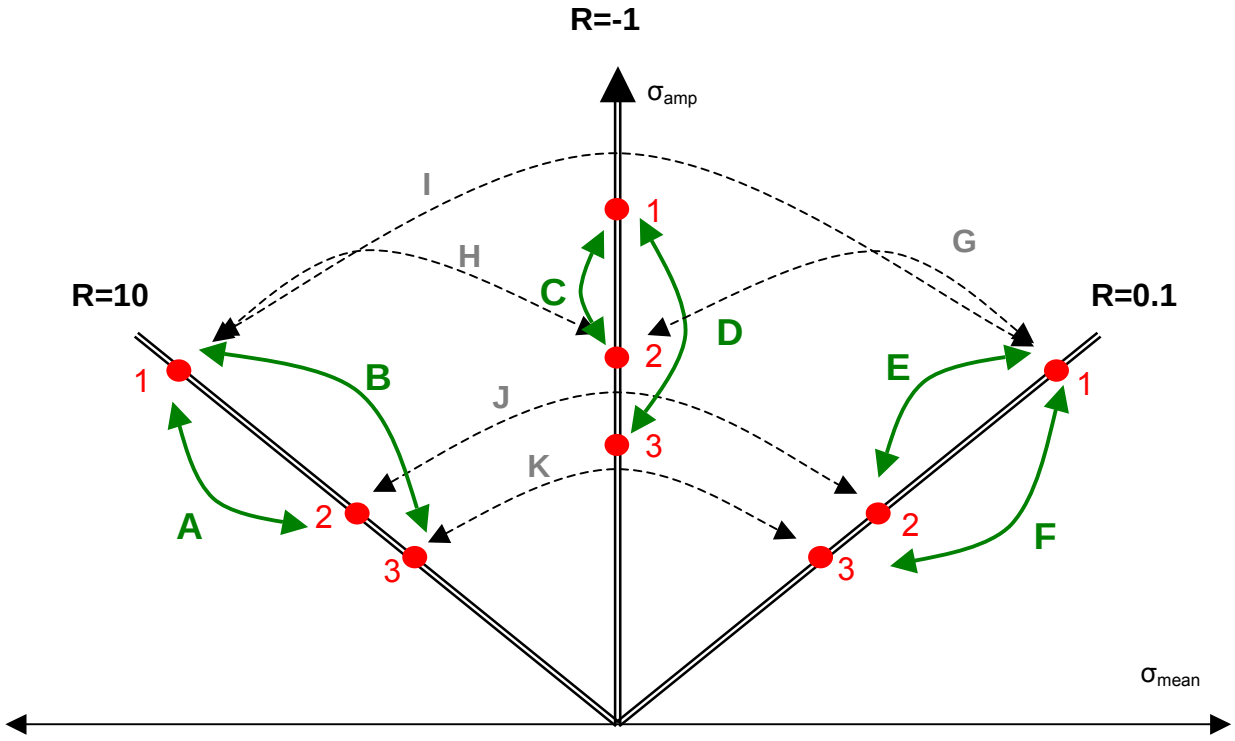

Figure 1. Available stress states for block testing of MD material in TG1
(Combinations of mean stress/amplitude for which residual strength degradation is determined in TG5 for both UD and MD)

Stress states

Figure 1 shows the combinations of stress ratio and amplitude for which residual strength curves are determined in TG5. Each red dot represents a 'stress state', so a 'stress state' is defined by R-value and stress level. Here, the stress levels corresponding to 10^3, $5{\cdot}10^4$ and 10^6 are defined as stress level 1, 2, and 3, respectively.

Stress state per block

Block tests consist of a (repeated) sequence of 2 blocks, in which stress state is constant per block. Since residual strength degradation will be tested for a limited number of stress states in TG5, it seems sensible to perform block tests using blocks composed of these stress states only.

Material tested in block tests

Only MD material is foreseen to be tested in block tests. Residual strength curves will become available for UD material also, but possible sequence effects and/or mutual influence of stress states will not be investigated in TG1 for UD.

Proposed block tests

The proposed block tests are indicated in table 1 and 2, these tables are also in the DPA.

Table 1:	Block tests I - 2-block, 1st to 0.5 N_F, 2nd block to failure						
Lay-up	**R_1**	**R_2**	**σ_1**	**σ_2**	**MD**		**see figure 1**
					DLR	**TUDT**	
axial	**-1**	**-1**	**1**	**2**	3	2	**C**
	-1	**-1**	**2**	**1**	3	2	**C**
	-1	**-1**	**1**	**3**	3	2	**D**
	-1	**-1**	**3**	**1**	3	2	**D**
	10	**10**	**1**	**2**	2	3	**A**
	10	**10**	**2**	**1**	2	3	**A**
	10	**10**	**1**	**3**	2	3	**B**
	10	**10**	**3**	**1**	2	3	**B**
	0.1	**0.1**	**1**	**2**	3	2	**E**
	0.1	**0.1**	**2**	**1**	3	2	**E**
	0.1	**0.1**	**1**	**3**	3	2	**F**
	0.1	**0.1**	**3**	**1**	3	2	**F**
	10	**0.1**	**1**	**1**	2	3	**I**
	0.1	**10**	**1**	**1**	2	3	**I**
	10	**0.1**	**2**	**2**	2	3	**J**
	0.1	**10**	**2**	**2**	2	3	**J**
	10	**0.1**	**3**	**3**	3	2	**K**
	0.1	**10**	**3**	**3**	3	2	**K**
	-1	**0.1**	**2**	**1**	2	3	**G**
	0.1	**-1**	**1**	**2**	2	3	**G**
	-1	**10**	**2**	**1**	3	2	**H**
	10	**-1**	**1**	**2**	3	2	**H**
Total					**56**	**54**	

Table 2:	Block tests II - 2-block, repeated, each block 1% of N_F						
Lay-up	**R_1**	**R_2**	**σ_1**	**σ_2**	**MD**		**see figure 1**
					DLR	**TUDT**	
axial	**-1**	**-1**	**1**	**2**	3	2	**C**
	-1	**-1**	**1**	**3**	3	2	**D**
	10	**10**	**1**	**2**	2	3	**A**
	10	**10**	**1**	**3**	2	3	**B**
	0.1	**0.1**	**1**	**2**	3	2	**E**
	0.1	**0.1**	**1**	**3**	3	2	**F**
	10	**0.1**	**1**	**1**	2	3	**I**
	10	**0.1**	**2**	**2**	2	3	**J**
	10	**0.1**	**3**	**3**	3	2	**K**
	-1	**0.1**	**2**	**1**	2	3	**G**
	-1	**10**	**2**	**1**	3	2	**H**
Total					**28**	**27**	

Block tests I

Block tests I consist of 2 blocks, where each block is any of the stress states in Figure 1. In the first block, the material is cycled up to 50% percent of its mean estimated lifetime (determined from SN-curve). In the second block, the material is cycled until failure. This block test is performed on a number of specimens, then the sequence of the two blocks is reversed and the same number of tests is done.

Block tests II

These tests consist of blocks with the same stress states as block tests I, however, there are some differences:

- For every combination of 2 stress states, the blocks are only 1% of estimated mean lifetime at the respective stress state
- The blocks are repeated until failure

Tests which could be eliminated in case of time problems

The block tests as described in the DPA are expected to deliver a valuable contribution to the tests found in literature. However, the number of tests is close to the minimum for adequate investigation of the sequence-/mutual influence effects. Nevertheless, some reduction must be considered. Possible elimination of block tests seems to be the least harmful for the overall testing programme.

This document advocates not to eliminate tests a priori, but to make a priority list of the following form:

Order of elimination	Type	Estimated no. of testbench-weeks gained by elimination
1	K	7
2	F	7
3	B	7
4	D	7

This color code is also used in the tables 1 and 2.

Rationale behind original block test proposal

In this revision, the background to the selection process has been moved to an appendix. It was more relevant at the time of writing revision 0 of this document.

APPENDIX: Some background on the selection of block tests

In principle, any possible combination of stress states could be tested in the test programme. Since full tests on a combination of two stress states require 'High-Low', 'Low-High', and repeated block tests, a minimum of 3·n specimens is needed per combination, if n is the number of specimens to get one datapoint. In the following, n is 3, so 9 specimens are needed per combination. According to figure 1, there are 36 possible combinations→36·3·n=324 specimens are needed. This may be too large an experimental effort, so a selection was made. In the following, this attempt to build an efficient test programme is detailed.

Proposed block tests – constant R-value, variable amplitude

Most obvious starting point is to do block tests where only amplitude varies (R-ratio is constant). About 18 specimens are estimated to be necessary for block tests I and II according to figure 2 (block I and II-tests indicated by 'C' and 'D'), although this may be a bit conservative.

The same figure can be drawn for R=10 and R=0.1. This would then describe any possible sequence-effects due to amplitude and mean stress→total amount of 54 specimens to perform tests A through F.

Note, that the number of cycles of the first block in the block tests I corresponds to 0.5 of N_f. In the block tests II, each block is 1% of the lifetime…

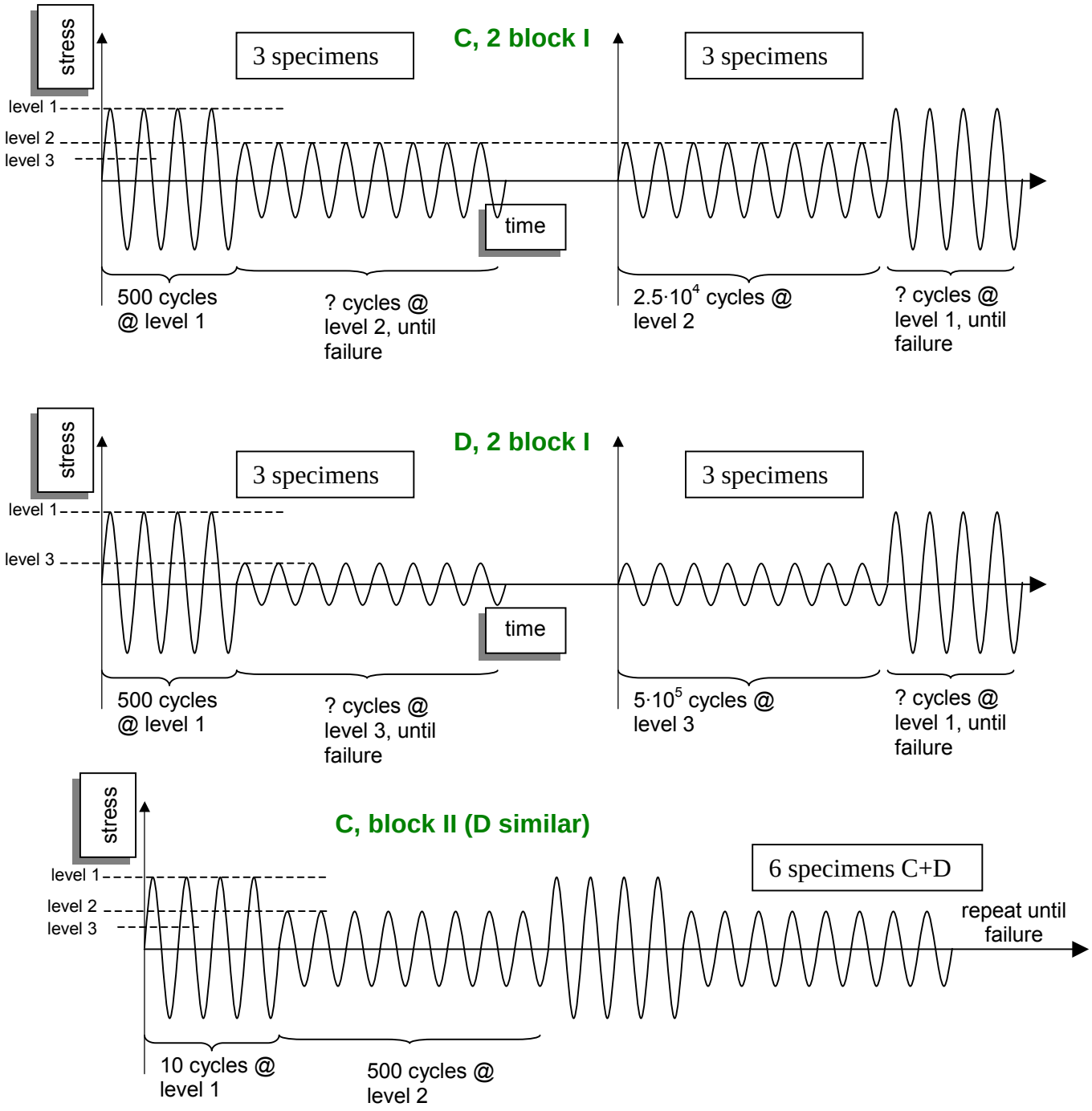

Figure 2: Block tests I and II (single R-value)

Proposed block tests – constant amplitude, variable R-ratio

Depending on the outcome of the SN-curve establishment it may also be possible to perform block tests where through the appropriate choice of levels, R-value varies, but stress amplitude is (almost) equal. These tests are indicated tentatively by G and H in figure 1. G-tests are shown in figure 3.

Similar tests, where block amplitudes are similar, but mean stress differs are I-K. These tests need at least 9 specimens per constant amplitude, varying R-ratio test.

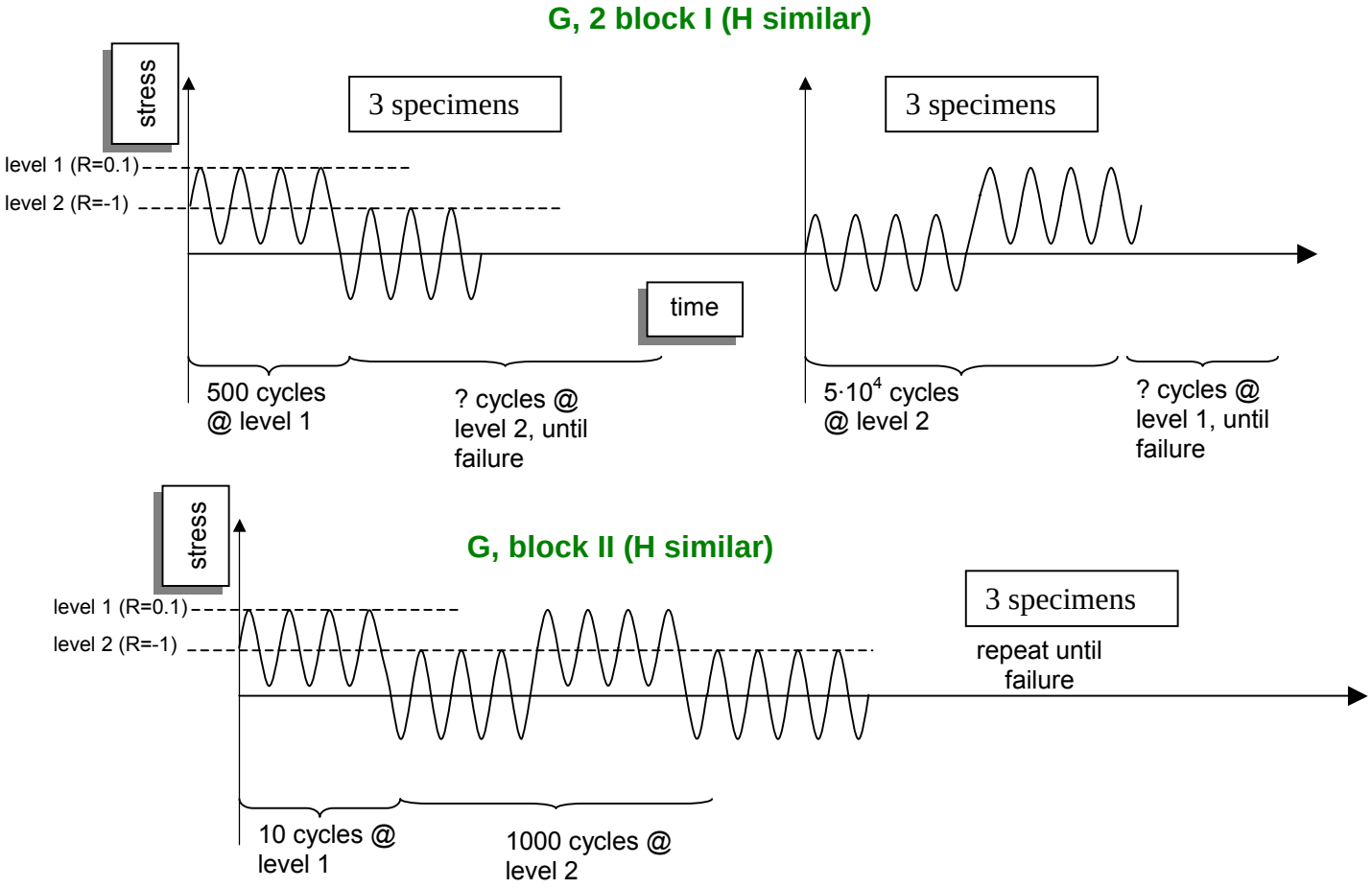

Figure 3: Block tests I and II (mixed R-value)

Proposed block tests – other permutations

Figure 1-3 only show a starting point for the block tests…in practice, all other combinations of stress states should be tested to describe possible sequence- and mutual interaction effects and to validate models. Figures 1-3 merely show one possible philosophy.

Peak load tests

Also, block tests where the lengths of the blocks are different, e.g. tests where a constant amplitude test is interspersed with load peaks can be done. Some examples of peak load tests are given in figure 4.

Table 3:		Peak load tests			
type	levels	1 peak every 1% and 10% of mean estimated low amplitude fatigue life (cycles)	random y/n	regular intervals y/n	no. of specimens
a	3-1 (1= peak)	10,000	n	y	3
	3-1	100,000	n	y	3
	3-1	10,000	y	n	3
	3-1	100,000	y	n	3
	2-1	500	n	y	3
	2-1	5000	n	y	3
	2-1	500	y	n	3
	2-1	5000	y	n	3
b…					24
c…					24
total					72

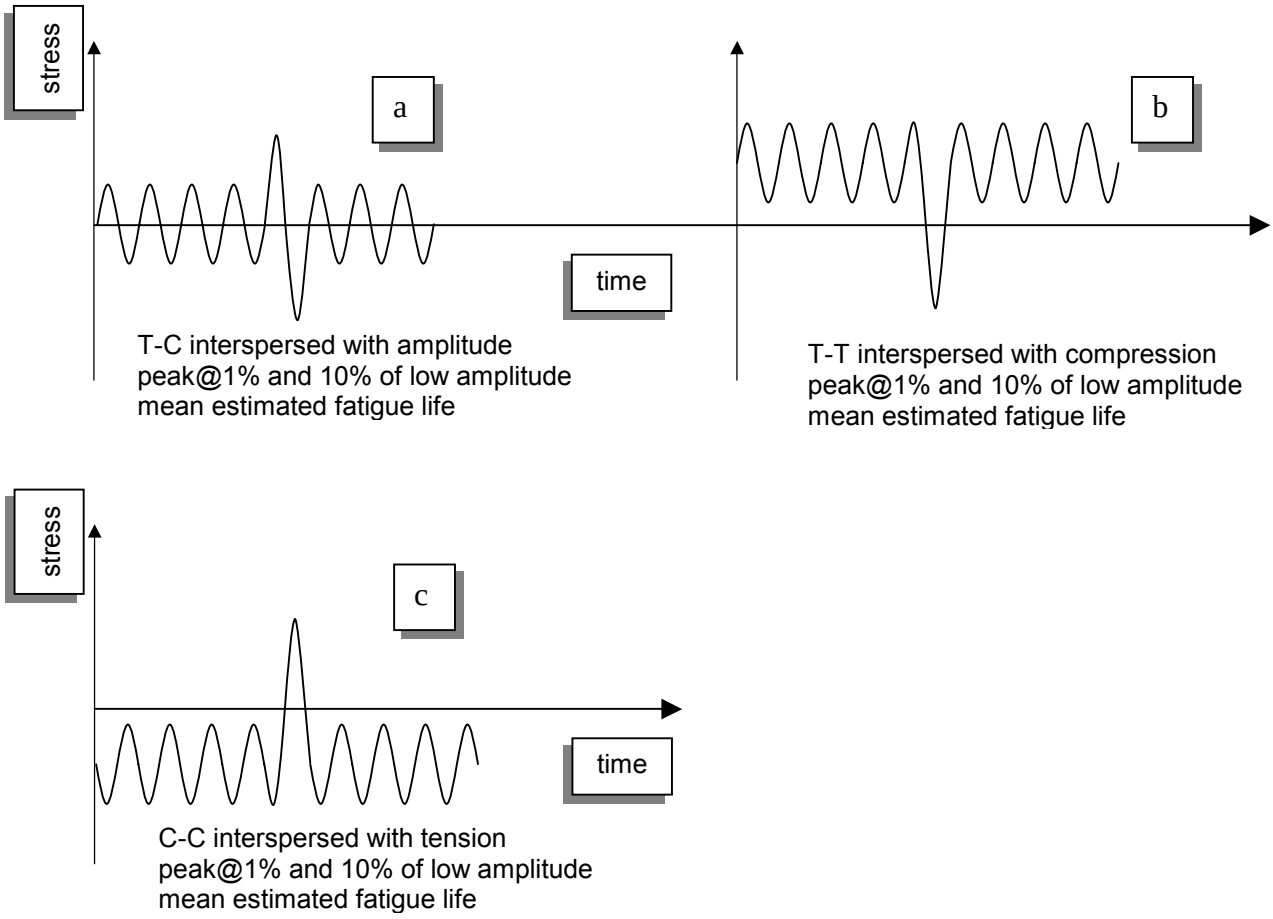

Figure 4: Other possible block tests: Peak load tests