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# TESTING ASPHALTS FOR SPECIAL EXPOSURES

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## Abstract

Airfield runways are generally made using cement concrete pavements, prone to be renewed by asphalt concrete layers, but sometimes the pavement has to meet special requirements.

The Department of Highway Engineering and the Institute of Thermal and Systems Engineering, TUB, cooperated in testing such special requirements. At first, heating and cooling caused by an airplane with low-mounted jet engine, applying an important heat load in preparing to take off, had been determined in field test, by means of an IR camera.

Thereafter two asphalt mixes have been laboratory tested by applying 100 cycles of in-situ, thermal effects. One was a conventional AB–20 type mix, the other a highly deformation resistant plastic asphalt. Asphalt changes after heat loads have been determined in bending fatigue tests.

The particularly high thermal effects were found not to be endured even by plastic asphalt mixes. On the other hand, impacts due to common airplanes are supported by conventional asphalts. Plastic asphalts have much lower bending fatigue lives, at higher building costs than for conventional asphalts. So construction of this kind of pavements would be meaningless. While alteration of operating conditions of airplanes imposing excessive heat loads would permit the use of asphalt concrete pavements in airfields.

*Keywords:* rolled asphalt runway, thermal effects on asphalt, plastic asphalt, bending fatigue tests, asphalt pavement thermometry.

## Introduction

Laboratory of the Department of Highway Engineering is equipped for great many different asphalt tests, of them a rather peculiar one will be presented.

Civilian and military airfields in Hungary have been made almost exclusively using cement concrete pavements. Also these pavements are subject to ageing, surface deterioration at some loss of load capacity, usually renewed by another thick cement concrete layer. To reduce building costs and time, the possibility to renew the surfaces of deteriorated, but structurally still adequate runways by asphalt concrete pavement has been considered. So that an asphalt pavement meeting special requirements had to be found.

In Western Europe, military airfields are often made using asphalt pavements. A properly dimensioned and composed asphalt pavement has an adequate resistance to loads and to rolling of airplanes taking off and touching down and to tracking. Obviously, however, in other than civilian air traffic, also airplanes with low-mounted jet engines are operating, blowing the emitted hot exhaust gases on the pavement at a small angle. This special effect due to such airplanes had to be investigated in-situ and in laboratory tests.

## Preliminaries to Field Tests

Field tests were expected to determine under strict conditions the heat load due to an airplane on its way to take-off, to be acquainted with heating up velocity and rate, cooling process, and other changes of the heated asphalt.

Following from characteristics of the exhaust gas jet emitted by the airplane drive, on one hand, the examined asphalt surface is exposed to thermal loads, on the other hand, a high-velocity gas flow has an erosive effect by impact and friction on the warmed asphalt surface. Because of pulsating and free flow of the gas jet, the heat transfer coefficient affecting the asphalt pavement surface temperature markedly varies with time.

Sensing the asphalt surface heating up is preconditioned by a proper metering apparatus, such as the IR camera type AGA THV 780 applied for testing the exhaust gas jet and the heat impact on the asphalt surface.

The cooling process of the heated asphalt surface is exempt from these dynamic effects, hence somewhat easier to follow.

Keeping the outlined complex thermal phenomenon in mind, primarily, temperature variation of the part of the asphalt pavement surface exposed to the highest heat load had to be determined.

In-situ IR thermogrammetry tests and thermal analyses of the asphalt surface warming up were made at the Institute of Thermal and Systems Engineering, TUB.

Experiments were made at an airfield with asphalt concrete pavement.

Test field layout is seen in *Fig. 1.* A 8 by 8 m square test area was marked out by metal marker disks 20 cm diameter. The IR camera was put in the middline of the test square, at 19.6 m from its centre, at a height of 4.7 m, to scan the test area at an angle of 11 to 16°.

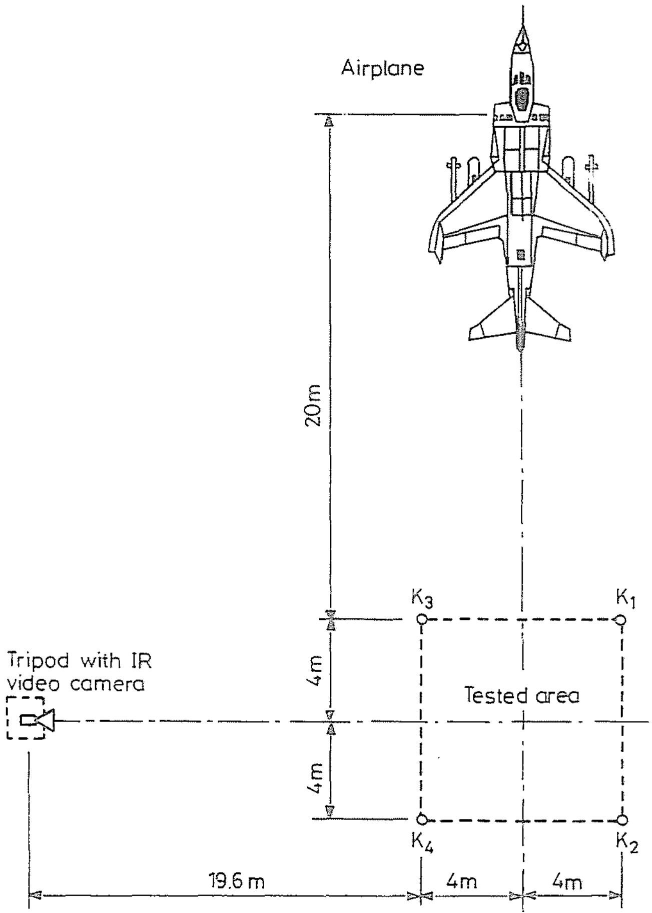


*Fig. 1.* Test field arrangement

## Field Tests

Field tests were made in early summer, in clear weather, sunshine, at an air temperature of 28 °C, wind velocity of 5 m/sec, and at a near asphalt surface temperature of 42 °C.

The airplane rolled to the test site and stopped with its fore wheel at 20 m from the test square.

The course of thermal interaction between asphalt surface and exhaust gas jet has been recorded during two consecutive rollings. The first loading by the first rolling (loading is understood here and subsequently as running up the drive to 100 % of the rpm) was preceded by about

1 min of instrument adjustment period, bringing the asphalt temperature to 60 °C (about corresponding to initial asphalt temperature in summer). This maximum asphalt temperature by the end of the second loading in the first rolling is that expected in summer, in an independent rolling.

The effect of exhaust gas jet gradually extended the heated area that got ever darker due to the melted bitumen. The hottest parts exhibited a boiling-like phenomenon, namely the centre of the heated area reached a temperature of 97 °C.

About 4 min after rolling, the airplane returned to its initial position, meanwhile its wheels crossed the heated area. Back at its place, the airplane repeated take-off operations, then switched to forceage and rolled away. Effect of the second warming was the same as that of the first one, but boundaries of the affected area extended. Upon switching to forceage, part of the melted bitumen on the surface burst into flame. The second warming had a deeper effect, partly due to the further penetration of the former warming up in the meantime. In the second rolling, the gas jet eroded the fine-grained material from part of the surface to a depth of 8 to 10 mm.

After both rollings, asphalt temperature and the cooling process were determined also by a contact thermometer.

This experimental heat load cannot be considered to correspond perfectly to the mode of operation, namely:

- the two starting positions were identical near to centimetres,
- at the first start, the airplane warmed the surface for a minute, during checking the measurement spot,
- there, rather than two run-ups to 100 % were made by the pilot.

In spite of these deviations, the experiment met its goal. The excess warming for one minute acted like making the test in the hottest summer, as seen in *Fig. 4*. Besides, coincidence of relocation and heat load may cause a similar random heat load as that for determining the 'ultimate condition'.

## Field Measurement Data

The exhaust gas jet left traces on the asphalt surface visible to the naked eye, but also resulted in thermal effects to be scanned only in the IR band. The former were photoed, the latter recorded in IR thermograms.

*Figs. 2* and *3* show two kinds of IR thermograms. One comprises so-called tonal pictures (*Fig. 2*) where darkness degree of the achromatic tone refers to the arising temperature value. In these IR pictures lighter tones indicate higher temperatures.

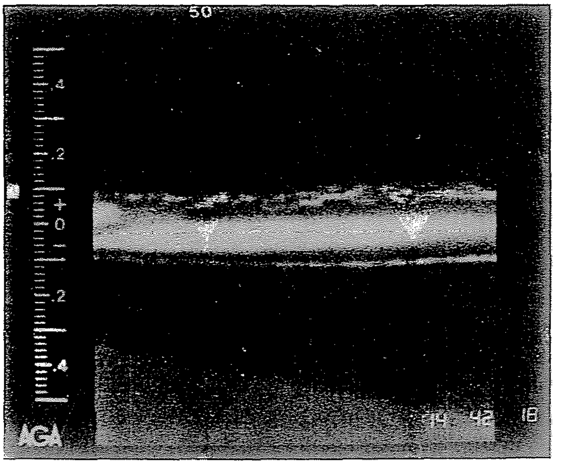


*Fig. 2.* IR tonal picture; lighter parts indicate warmer areas

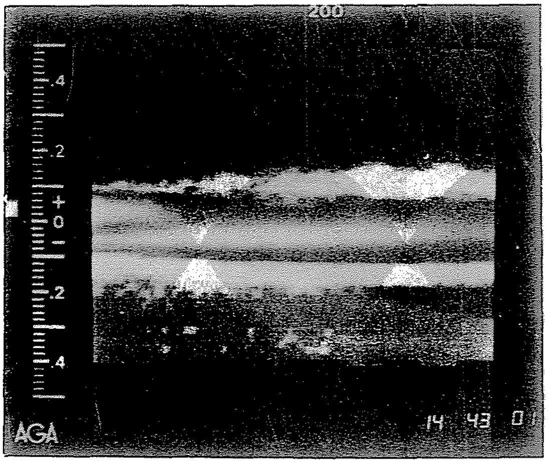


*Fig. 3.* IR iso-band image; the white line locates spots of equal temperature

The other is the so-called iso-band picture (*Fig. 3*) where location of a specified temperature level is marked by a white contour band marginal to the exhaust gas jet, the temperature level being indicated by a white marker square on the left side of the picture (at +0.1). In the actual case, the iso-band in the thermogram has been selected so that isothermal loci marginal to the exhaust gas jet about 7 to 8 m wide are indicated by a white band, apparent at the lower and upper edges of the jet.

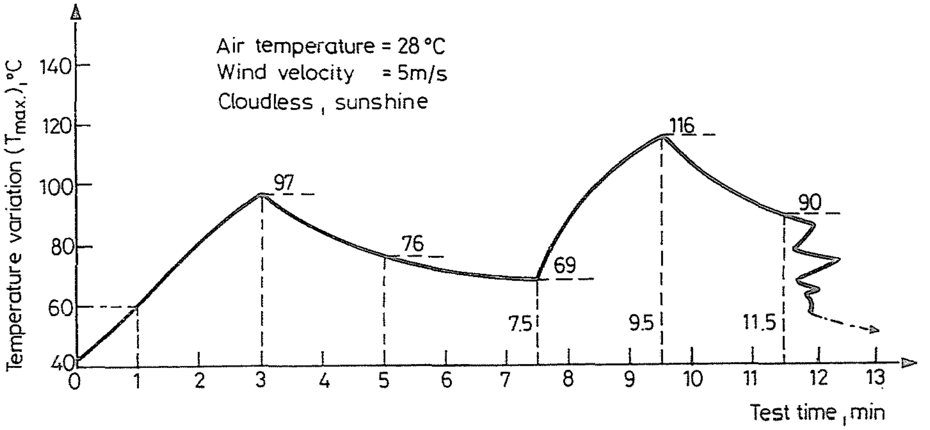


*Fig. 4.* Temperature variation of the asphalt surface

*Fig. 5.* Site after the field test

Irrespective of this iso-band, other parts of the IR image may be considered as tonal images. Thus, in the middle of the exhaust gas jet, an asphalt surface heated in max. 4 m width appears, on one hand, of variable width, on the other hand, of a temperature decreasing toward the edges.

Measurement results, IR thermograms were evaluated by replaying on video tape recorder, changing the iso-band location. Omitting details of evaluation, results have been recapitulated in *Fig. 4*.

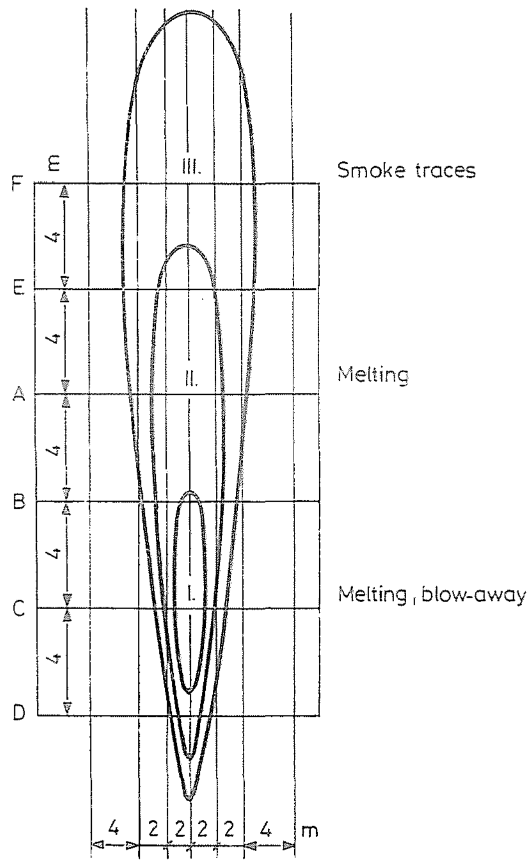


*Fig. 6.* Visible effects at the test site

Local maximum mean temperature $t_{max}$ found in site measurements has been plotted in *Fig. 4*. The experimental temperature variation is seen in smooth line. Dashed line represents variation without 1 min of pre-heating.

The experimental curve traces warming of the asphalt surface before rollings I and II, as well as the intermediary and ulterior cooling processes. Typical temperatures have been specially indicated in the diagram.

Photo in *Fig. 5* represents the post-experimental condition of the asphalt pavement.

Making use of perspective construction on an important enlargement of the photo, and of knowledge of the marker disk square data, boundary zones of heat load could be deduced. *Fig. 6* shows straight lines and boundary curves retransformed in plane.

Effects on the surface have been classified into three categories.

### *I. Melting, Erosion*

Within this area (about 7 by 1.5 m) thermal effect due to the airplane melted bitumen and asphalt binder to depths of 8 to 10 mm in the middle, and 2 to 3 mm at the edges, then the jet blew out first the mortar, then unsupported minor crushed stone from the surface. After the experiment, only crushed stone 15 to 20 mm, deeper embedded, was left in the midline.

### *II. Melting*

Within the test area bitumen has melted to a slight depth (1 mm) in the asphalt pavement surface, that was insufficient for the eroded mortar to be blown off the surface.

### *III. Smoke Traces*

In this area, surface bitumen softened for a short time, while in switching to forceage, burning exhaust gas left its traces.

An essential observation made in field tests was that warming would do much less harm in itself, were it not for erosion by the high-velocity gas jet 'removing' the melted asphalt. Typically, matter blown away from area I was found at 50 to 60 m from the test area, in a strip 30 to 40 m wide.

## Laboratory Tests

The original test goal was to determine mechanical properties of the asphalt altered by a high cycle number of in-situ heat loads. Field observations, however, showed it to be meaningless, namely after five or six repetitions, no more asphalt is left to be tested.

Therefore it was decided to test the effect of a reduced impact, that, if endured by the asphalt, will be suggested to be specified for operating conditions. Field tests show that the drive test of the daily first take-off can be made in 80 to 90 sec, while the asphalt temperature does not exceed 80 °C at first. Another possibility is to alternate take-off sites, increasing thereby cooling time intervals between warmings.

An essential feature of materials is to undergo structural, physical, chemical changes upon repeated stresses, entraining — in final account — failure of the material, loss of resistance to stresses after a given cycle number.

These tests, although destructive, are not instantaneous but rather lengthy, yielding — in turn — more information than do single static load tests. Dynamic bending-fatigue tests are just aimed at showing fatigue characteristics of the asphalt layer upon alternating tensile-compressive stresses, or shorter service lives to be expected.

Therefore bending-fatigue tests were made to determine specimen alterations.

## Tests Specimens

Specimens were made from the material of the airfield asphalt pavement, an AB–20-type asphalt concrete wearing course of conventional composition, made using bitumen B50.

At an increased temperature, the traditional asphalt concrete gradually looses its undeformability, tried to be offset by applying hard bitumen, yielding, however, an asphalt prone to cracking in cold weather.

Tests are going on world-wide to find recent types or materials better resisting both winter cracking and summer deformation than do asphalts of conventional composition.

Such a recent-type surfacing material is that with the trade name 'salviacene' (introduced in this country by the name MÜFALT), of mixed composition, in particular.

No-fines rubble size 12/20 as usual in this country is hot impregnated with bitumen of nominal penetration 30 to 45. This mix is applied, compacted as usual. No-fines crushed stone provides for a skeleton with an important voids ratio hence capacity (drain-like), and a significant internal friction. A previously carefully designed and mixed mortar of cement-sand-plastic (in general, polyvinyl acetate) is compacted by platform vibrator into voids of the mineral skeleton. Mortar part of the system behaves thereby as a stiff material, although plastic admixture favourably affects visco-elastic properties.

The asphalt 'MÜFALT' was adopted in the tests for its high undeformability and for favourable observations made previously with it.

Nine prism asphalt specimens 60 x 80 x 300 mm each were made compacted by vibration.

## Laboratory Heat Load Fatigue Tests

Asphalt and plastic-admixed asphalt specimens were subjected to moderate heat load tests as seen in *Fig. 7*. Specimen mid-parts were heated, the propane-butane gas burner was arranged so that the flame did not directly contact the asphalt surface, hence with no direct bitumen burning.

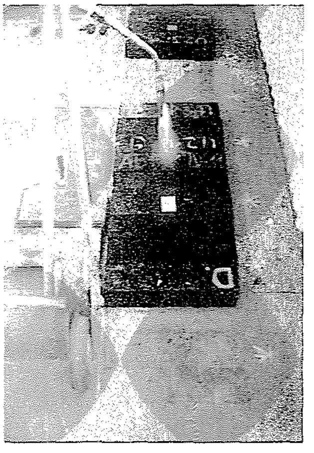

*Fig. 7.* Laboratory heat load test

Specimens were heated for 1.5 min each, so that surfaces warmed up to 80 to 85 °C. Between heatings, 7.5 min cooling intervals were left. After twenty heatings of a specimen, several hours of intermission were left. Specimens were submitted to 100 heating periods.

In planning the experiment, wind erosion due to the jet engine was not simulated, assuming in fact no erosion to occur at warming up to this temperature.

Surfaces of AB–20 asphalt specimens softened to a slight depth, bitumen and fines melted under heat load.

MÜFALT specimen surfaces were somewhat discoloured, browned. Bitumen emerged spot-wise to the plastic surface. Specimens visibly did not suffer any serious damage.

These MÜFALT specimens having well endured moderate heat loads were subjected to full heat loads as observed in field tests. It was planned to apply 100 test cycles but after 20 cycles it was stopped since both plastic and bitumen were burnt out of the specimens. Because of different thermal expansion coefficients of plastics, cement and asphalt components, cement-plastic mortar surface layers abruptly blasted off.

## Bending Fatigue Tests

Scheme of the bending fatigue test is seen in *Fig. 8*. Bending was made under control stress, the force alternated at 4 Hz frequency, according to sine function, in the $\pm F_{max} = 2500$ N range, about 30 % of static ultimate load. During the test, specimens were kept at +5°.

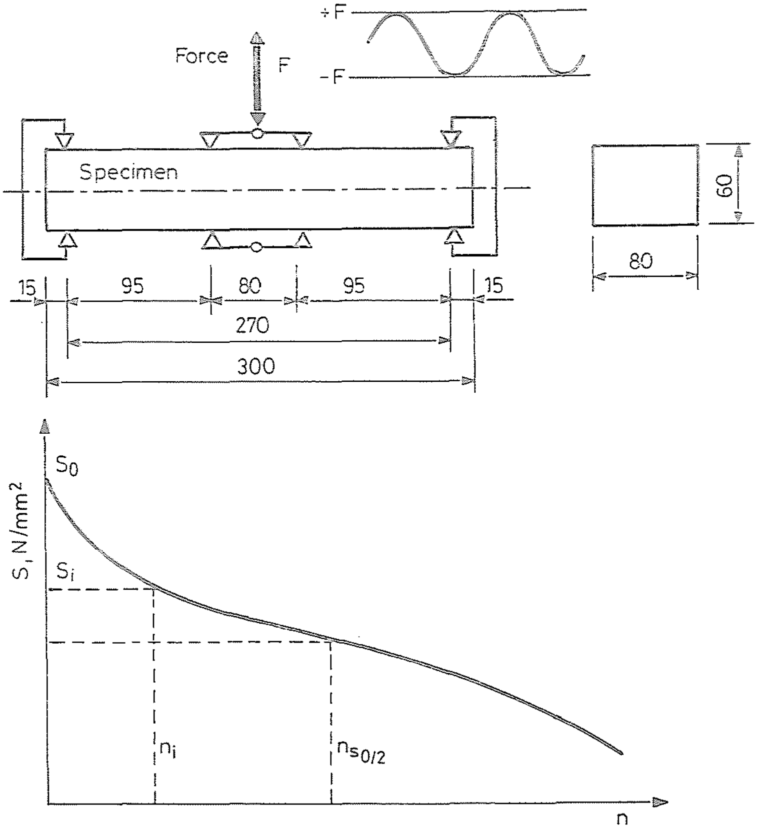


*Fig. 8*. Bending fatigue test

Tests were continued until specimen failure where deflection abruptly increases. During the tests, specimen deflections were measured and recorded regularly, ten to twenty times.

Invariable geometries, load, mid-section thickness of specimen (b) and actual (varying) deflection permit to calculate for different cycles numbers n the stiffness moduli $S$ of the specimen material (N/sq.mm). Fitting a

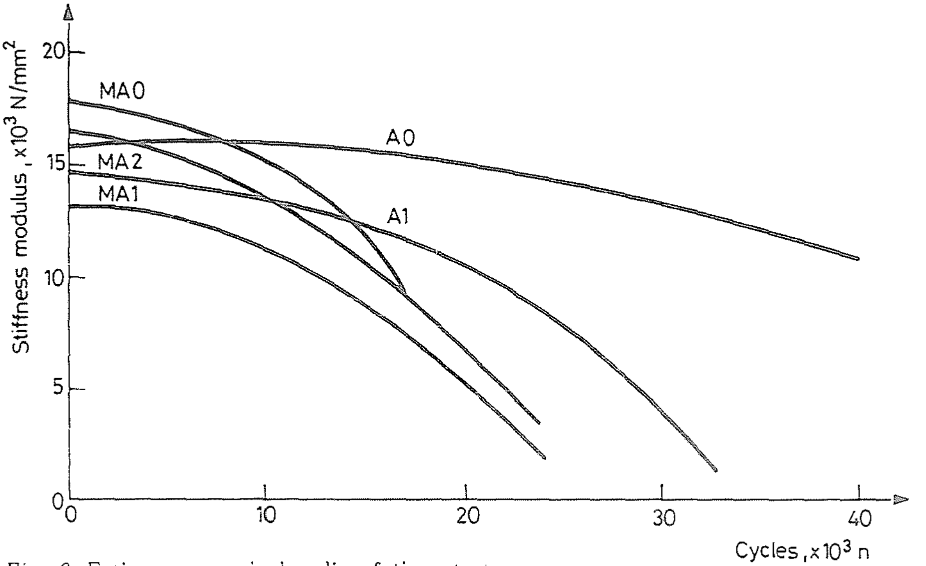


*Fig. 9.* Fatigue curves in bending fatigue tests
A0– asphalt concrete specimen without heat load
A1– asphalt concrete specimen after 100 heat load cycles
WA0– plastic-admixed specimen without heat load
MA1– plastic-admixed specimen after 100 heat load cycles
MA2– plastic-admixed specimen after 20 full heat loads

**Table 1**
Bending fatigue test results

| Asphalt type | Heat load | Initial stiffness [N/mm$^2$] | Fatigue life cycles |
|---|---|---|---|
| Asphalt concrete | Without ... A0 | 15890 | 56100 |
| | After 100 ... A1 | 14630 | 25900 |
| Asphalt concrete with plastic | Without... MA0 | 17640 | 17200 |
| | After 20 ... MA1 | 13100 | 19400 |
| | After 100 ...MA2 | 16520 | 18000 |

third-regre regression polynomial to fatigue curve points $n - S$ of similar specimens, coefficients of this function and/or the cycle number $N$ (service life) at half of the initial stiffness obtained from these coefficients (So/2) are the test results. Cycle number $N$ is generally considered as 'service life' of the material in a mode of operation involving the applied stresses.

Regression fatigue curves are seen in *Fig. 9*. Essential test data have been compiled in *Table 1*.

## Evaluation of Test Results

Test results reflect adequacy of the experimental conception.

It is known since long that the effect of some change in the inner structure of a material is likely to be the best observable from its behaviour under repeated stresses.

Comparison of fatigue characteristics of the two materials exempt from heat load obviously favours the coarse asphalt concrete. Initial stiffness moduli are about the same (at +5 °C), but the cycle number in the fatigue life of the asphalt is about four times that for plastic asphalt specimens.

Fatigue lives of coarse asphalt concrete specimens having endured 100 cycles of heat load dropped to less than half the cycle number ($N =$ 25900), indicating — if not exactly but approximately — the really arising proportions.

The effect of heat load seems to somewhat increase fatigue lives of plastic asphalt specimens.

Multiple heatings gradually compounded the two materials (plastic-cement mortar and asphalt), visible from bitumen spots apparent on the pale mortar surface. Nevertheless, even the increased cycle number falls short of the reduced fatigue live of coarse asphalt concrete. Obviously, since the plastic asphalt skeleton misses asphalt mortar, and with it, part of the bitumen binder, about 30 % compared to the AB–20 asphalt. Test results show plastic and cement cannot compensate this missing of the bitumen binder.

In final account it can be stated that coarse asphalt concrete (AB–20) can only endure such a fatigue heat load at an abrupt decrease of its fatigue life. Heat load cycles little affect fatigue life of plastic asphalt that is a priori much less in bending cycles. Neither does plastic asphalt endure unmoderated heat loads.

## Conclusion

Performed field and laboratory tests showed conventional asphalt materials not to endure extreme heat loads applied by the concerned airplane type. Laboratory heat load and bending fatigue tests showed a high cycle number of — although reduced — heat loads to significantly deteriorate the asphalt.

Degradation of plastic asphalt mixes arises at full heat loads. These materials are rather resistant to moderate heat loads. Bending fatigue lives of plastic asphalt mixes are, however, much less, while building costs are much higher than for conventional asphalt pavements.

As shown by Western European practice, and as demonstrated by the Department of Highway Engineering in previous tests, asphalt concrete suits as pavement for airfield runways. But operation has to reckon with asphalt properties, controlling jet engine tests for airplane awaiting take-off. Relevant research report by the Department of Highway Engineering suggests ways of control to be introduced.

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