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TECHNISCHE UNIVERSITÄT MÜNCHEN
PRÜFAMT FÜR BAU VON LANDVERKEHRSWEGEN

Univ. Prof. Dr.-Ing. G. Leykauf

TEST REPORT

Client: Fa. Getzner Werkstoffe, A-Bürs/Bludenz

Ordered tests: Static stiffness on sub ballast mats, removed from a rapid transit track in Munich, Germany

Specimens: 2 pieces Sylomer® B 851
dim.: 300 x 300 x 55 mm

- This report includes 4 pages and 9 appendices -

1. PROCEEDINGS

In the year 1983 sub ballast mats (SBM) of type Sylomer® B 851 made by Getzner Werkstoffe GmbH have been installed into the rapid transit tunnel in Munich (section Isartor – Rosenheimer Platz). The reason for this measure was that the cultural centre, especially the concert hall of the Philharmonic Orchestra, had to be protected against the structure-borne noise caused by the rapid transit traffic in the tunnel. The stipulated high effectiveness was proved by acoustic measurements immediately after the installation. Up to now no change of the effectiveness could be realised.

In the night from 01.12.1999 to 02.12.1999, after more than 16 years in operation, two samples of the SBM have been removed (at two defined locations) by order of Getzner Werkstoffe GmbH under supervision of the Deutsche Bahn AG for to examine the long-term properties of the product.

According to the information of the Deutsche Bahn AG the rapid transit tunnel in Munich is the highest frequented rapid transit line in Germany. From 1983 up to now the daily traffic density on section increased from 100.000 load tons up to 150.000 load tons. As a result on the SBM was exposed during the whole time of its installation with more than 760 million load tons. Due to an axle load of 16 tons (rapid transit train unit of Munich's railcar type ET 420) this corresponds to more than 45 million load cycles; in comparison with the demand for approval in the new Technical Terms of Delivery for SBM of the Deutsche Bahn AG (DB TL 918 071), a fatigue test in the ballast through with 12,5 million cycles (load) must be endured.

The superstructure in the tunnel consists of the rail S 49, wooden sleepers with a spacing of 600 mm and a height of ballast of ≤ 35 cm. The operating conditions on the superstructure results from the rapid transit railcar train of the Deutsche Bundesbahn (type ET 420) with 16 tons axle load and a maximum speed of 80 km/h.

The SBM samples have been removed at mileage point 2,714 (normal ballast level, track curve) and at mileage point 2,762 (extremely low ballast level, straight rail), both from the middle of the sleeper spacing to the neighbouring one and from beginning of the load area at the end of the sleeper to the center of the sleeper (> ½ length of sleeper). Dimensions of the removed parts: about 600 mm x 1300 mm.

2. TESTS AND RESULTS

2.1 Visual inspection

The SBM laid in water on the tunnel floor in both cases and the samples had to be dried before testing by comparability reasons with the values before installation.

On the SBM the imprint marks caused by the ballast grains are clearly to see. In comparison with SBM-material taken from other parts of the track, no load-distribution-cone of the sleepers emerged on the mat surfaces.

The load distribution layer (protection layer in the contact area against the ballast) is in a very good condition; it shows slight plastic deformations caused by ballast but no damages (perforation).
The imprints of the ballast show that the ballast grains are very well imbedded in the mat's surface. Both of the resilient layers are completely intact and show the same stiffness when installed.
The adhesive layer between the load distribution layer and first resilient layer is porous and has no linking/adhesive effect anymore. But this is not relevant for the functionality of the SBM, however.

2.2 Static stiffness

As a part of the quality control process the static modulus of reaction has been documented (evaluated as secant value between 0,1 and 0,2 N/mm²), measured according to the stipulations of the tender on 1 % of the delivered SBM (date: 03.02.1983, see report of acceptance GÜ 32/83, Munich University of Technology, Prüfamt für Bau von Landverkehrswegen). Corresponding to this report, the set value of the tender with a modulus of reaction of C = 0,008 ± 0,001 N/mm³ has been met extremely well the for the delivered SBM material type Sylomer® B 851 with $C_{measured}$ = 0,0076 ± 0,001 N/mm³ (loading rate v = 0,1 N/mm³ per min = 0,16 kN/s).

Schedule:

Sources of the Values	Static modulus of reaction (evaluated between 0,1 und 0,2 N/mm²) [N/mm³]	Deviation from requirement [N/mm³]	Deviation from requirement [%]
Requested value by the tender and quality control of 03.02.1983	0,008 ± 0,001 bzw. ± 15 %	-0,0004	5,2
Removed sample 1 01./02.12.1999	0,0087	0,0007	8,7
Removed sample 2 01./02.12.1999	0,0089	0,0009	11,25

The test of the two removed SBM's (dimensions of sample 200 mm x 200 mm, loading rate 0,17 kN/s) showed an average static modulus of reaction of C = 0,0088 N/mm³ (appendix 1 and 2). Therewith the stipulated value of the tender (C = 0,008 ± 0,001 N/mm³) still is met, in spite of the great strain and the long time of its installation. The load-deflection-graph of the samples show a slightly stiffer behaviour of the mats as before installation.

2.3 Dynamic stiffness

The determination of the dynamic stiffness takes place at the equipment of Müller-BBM institute (see app. 6 to 9). As before the installation, a very low influence to the dynamic stiffness from the increasing load and the introduced frequency is to notice: the stiffness increases between 10 and 100 Hz and a preload range from 0,03 to 0,10 N/mm² only from C = 0,03 to 0,04 N/mm².

3. SUMMARY AND EVALUATION

After a time of installation of more than 16 years and with more than 760 million load tons in operation, samples of the SBM type Sylomer® B 851 have been removed and tested by visual inspection and recording its stiffness.

The essential results can be summarised as follows:

- From visual inspection the SBM have full functionality.
- The imprints of the ballast grains show that the ballast is imbedded in the mat's surface very well. No visible load-distribution-cone under the sleeper emerged on the mats.
- The difference in static stiffness between the removed samples and the stipulate value in the tender is 11 % maximum. With regard to the requirements of the tender from the year 1983 the values are at the upper limit of tolerance and the todays stiffness meets the requirements of the tender.

The summarising assessment is that Sylomer® B 851 SBM endure extremely well an exceptional high strain of 760 million load tons under operation during more than 16 years.

Due to this results, the full functionality of the SBM can be expected for at least another 30 years under the condititionthe strain on the mats remains on the same level.

For further clarification we recommend another remove of samples in about 10 years respectively 500 Mio load tons.

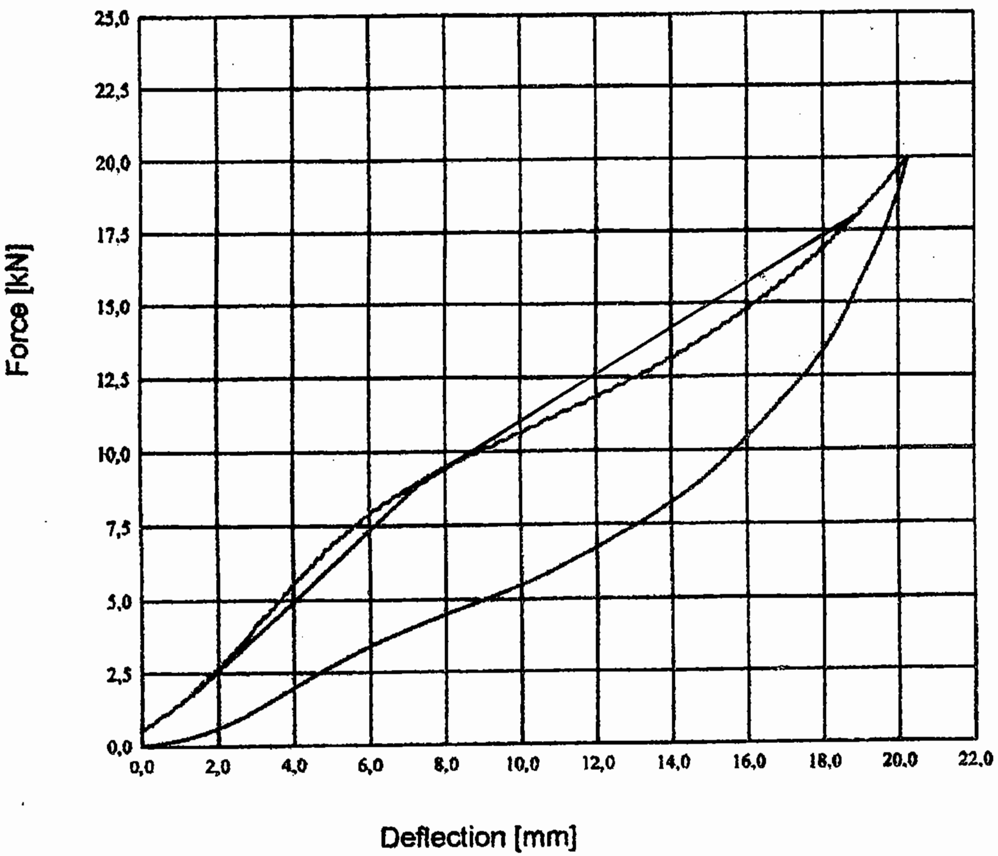
München, 27.10.2000

(Dr.-Ing. F. Deischl)

SBM Sylomer B 851

Static calibration, 3rd load and unload graph, loading rate 0,16 kN/s

Dim.: 300 x 300 mm specimen No. 1



Spring coefficient
$C_{0,02\text{-}0,10}$ = 1,19 kN/mm

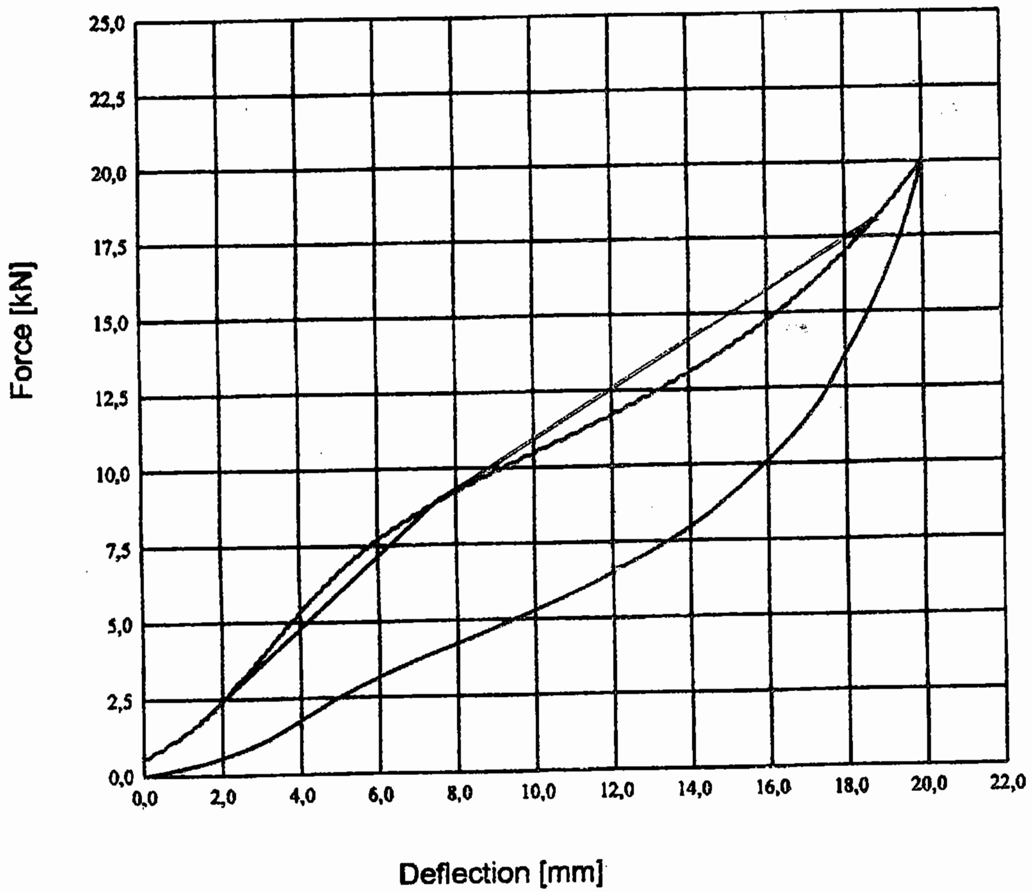
Damping
D = 37,26 %

Modulus of reaction
$C_{0,10\text{-}0,20}$ = 0,0087 kN/mm³

SBM Sylomer B 851

Static calibration, 3rd load and unload graph, loading rate 0,16 kN/s

Dim.: 300 x 300 mm specimen No. 2



Spring coefficient
$C_{0,02\text{-}0,10}$ = 1,19 kN/mm

Damping
D = 38,91 %

Modulus of reaction
$C_{0,10\text{-}0,20}$ = 0,0089 kN/mm³

Fig. 1: Removing of the SBM - opening of the sleeper spaces

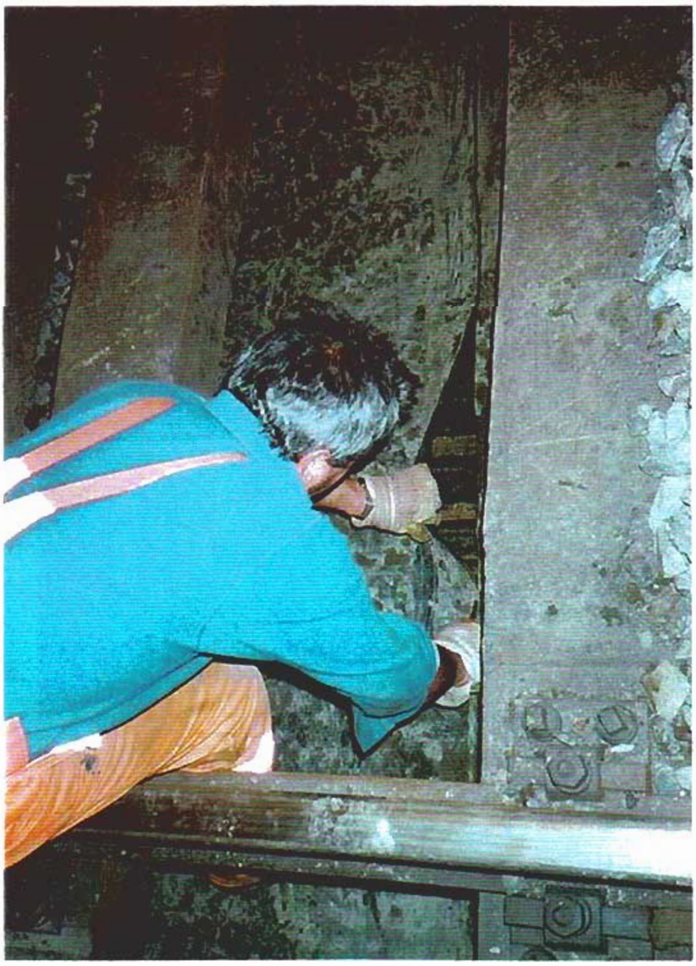


Fig. 2:

Removing of the upper layer

Fig. 3:

Removing of the SBM at the outside sleeper space

Fig. 4: Exposed area - visible is the lower SBM-layer

Fig. 5:

View to the area of the removed SBM; under the end of the sleeper the tunnel floor is visible

Fig. 6:

Water on the tunnel floor in which the SBM is dipped in

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Dynamic stiffness of a ballast mat type Sylomer B-851 after 17 years of use in the tunnel near Kulturzentrum GASTEIG in Munich

Manufacturer:
Getzner Werkstoffe Ges.m.b.H.
Bludenz/Bürs, Austria

Test report No. 44 953 / 7 E

Client:	Getzner Werkstoffe Ges.m.b.H. Herrenau 5 A-6706 Bürs/Bludenz ÖSTERREICH
Acoustical consultant	Dipl.-Ing. (FH) P. Hofmann
Date:	01.12.2000
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DQS-zertifiziertes Qualitätsmanagementsystem nach DIN EN ISO 9001 (Nr. 5338)
Akkreditiertes Prüflaboratorium nach DIN EN 45001 (DAR Reg.-Nr. DAP-P-02-005-00-93-01)

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Geschäftsführer:
Dr. Gerhard Müller, Dr. Joachim Scheuren

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5. Measuring equipment

To carry out the tests the following measuring equipment was used.

Table 1: Measuring equipment

	Manufacture	Type
Force transducer	Kistler	9051 A
Accelerometer	Brüel & Kjaer	4371
Accelerometer	Brüel & Kjaer	4370
Charge amplifier	Kistler	5011
Charge amplifier	Brüel & Kjaer	2635
Shaker	Brüel & Kjaer	4801/4812
Power amplifier	Brüel & Kjaer	2707
FFT-Analyzer	Hewlett Packard	3562 A

6. Calibration of test facilities

All equipment for force and acceleration measurements were calibrated. A test with a reference standard was carried out (steel spring with known properties). The calibration procedure was repeated after the tests.

7. Standards and specifications

The tests for the determination of the dynamic stiffness per unit area were carried out according to the following standards:

- ISO 10 486-2

  Acoustics and vibration laboratory measurements of the vibro acoustic transfer properties of resilient elements, Part 2:
  Dynamic stiffness of elastic supports for translatory motion - Direct Method.

- Technical delivery standard for ballast mats of the „Deutsche Bahn AG" TL 918071.

8. Measuring procedure and measuring conditions

The dynamic stiffness per unit area was determined under the following test conditions.

Number of test specimen:	1
Size of the test specimen:	approx. 200 x 200 mm²
Static preload:	F'' = 0.03 / 0.06 and 0.10 N/mm²
Excitation velocity:	L_v = 98 dB re $5\cdot10^{-8}$ m/s (in the frequency range f ≥ 20 Hz)
Temperature:	approx. 24°C
Humidity of air:	approx. 60 %

9. Results

The figure in the annex shows the dynamic stiffness of the used ballast mat type Sylomer B-851 manufactured by Getzner Werkstoffe Ges. mbH as function of the static preload F'' = 0.03 / 0.06 and 0.10 N/mm² in the frequency range up to 200 Hz.

Measurements in the static preload range of F'' = 0,01 N/mm² have not been carried out as for this range there was no sufficient coupling between ballast mat and the surface of the test rig.

The dynamic stiffness per unit area hardly shows any differences for the static preload F'' = 0,03 and 0,06 N/mm². If the static preload is raised to F'' = 0,10 N/mm² the dynamic stiffness per unit area decreases by a small amount.

As usual, the dynamic stiffness per unit area increases with frequency.

The following table shows the measured dynamic stiffness per unit area of the test specimen for selected frequencies.

Table 2: Dynamic stiffness per unit area „Sylomer B-851"

Static preload F'', N / mm²	Dynamic stiffness s'', N / mm³ Frequency, Hz 20	40	60	80	100
0,03	0.0396	0.0430	0.0450	0.0468	0.0489
0,06	0.0402	0.0436	0.0455	0.0475	0.0493
0,10	0.0356	0.0388	0.0406	0.0425	0.0442

1. Task

The dynamic stiffness per unit area of a test specimen of a ballast mat type Sylomer B-851 manufactured by Getzner Werkstoffe Ges. mbH should be determined in accordance with the delivery specification for ballast mats (USM) of the Deutsche Bahn AG: TL 918071 (DB-TL).

The ballast mat was produced in 1982/1983 and installed in the S-Bahn (rapid transit system) tunnel near the Kulturzentrum Gasteig in Munich. During inspection works on the railroad track in 2000 a sample of the ballast mat was taken to test the dynamic stiffness after 17 years of use.

2. Test specimen

The tests were carried out on a sample of the ballast mat Sylomer B-851. The dimension of the test speciment was 200 x 200 mm².

Structure of the ballast mat:

The ballast mat Sylomer B-851 consists of three different layers with a total thickness of approx. 51 mm[1].

Upper layer:	Protective layer, thickness approx. 8,5 mm
Middle layer:	Thickness approx. 21,5 mm
Lower layer:	Thickness approx. 21,5 mm

When the ballast mat was taken from the tunnel in 2000 the adhesive material which had gone brittle was broken and the layers were disconnected.

Samples were taken from these layers. The sample given to Müller-BBM consists of three single parts. However, the position of the mounted layers is unknown.

To carry out the tests the test specimen were cleaned from the remainders of the adhesive substance and reconfigurated according to the original structure of ballast mat type B-851.

3. Test procedure and test facilities to measure the dynamic stiffness

The target of the test is to find a physical quantity which describes the test specimen independent of the testing apparatus and the application in-situ. This physical quantity is determined by the transfer impedance with blocked output.

The dynamic stiffness of the test specimen is calculated from the transfer impedance. The dynamic stiffness per unit area is obtained by normalizing the dynamic stiffness to the size (length x width) of the sample.

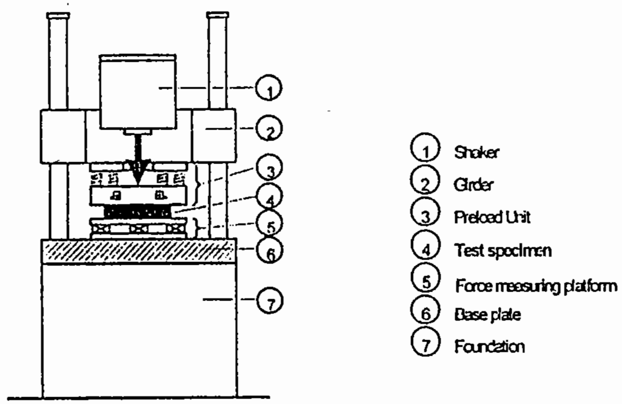
[1] measured after carrying out the tests

To determine the complex transfer impedance of the sample it is mounted on a foundation of high input impedance and excited with a shaker at its upper side. The transfer impedance „force/velocity" is calculated from the measured velocity on the upper side of the sample and the force measured on the foundation.

4. Test arrangement

The test arrangement is shown in the following drawing.

The test specimen (4) is seated on the base plate (6) on a force measuring platform (5). The static load is adjusted with a hydraulical controlled girder (2) with a dynamic preload unit (3). The shaker (1) excites the preload unit. The oscillation force is superimposed with the static preload.



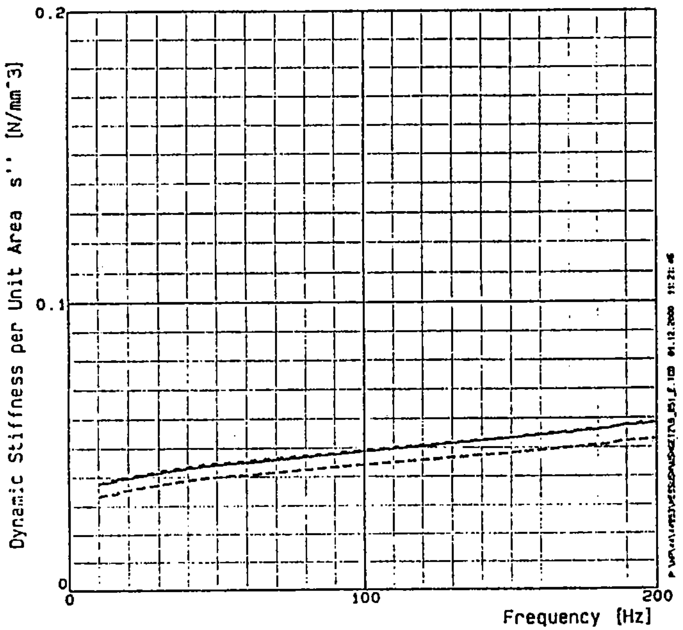
Test rig to determine the dynamic stiffness

The oscillation force F and the velocity v are measured with a FFT-Analyzer; the transfer function F/v is calculated.

Dynamic Stiffness per Unit Area

USM B-851 after 17 years used in a railway tunnel

Manufacturer: Getzner Werkstoffe GmbH/Bludenz/Austria



Dynamic stiffness per unit area related to static preload

- ——— Static preload F' = 0.03 N/mm^2
- - - - - - Static preload F' = 0.06 N/mm^2
- - - - - - Static preload F' = 0.10 N/mm^2

Picture 1

The results of the samples taken after 17 years of use are comparable to those made on samples prior to installation in 1983.

Responsible for the technical contents:

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