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Prüfung, Überwachung, Zertifizierung, Beratung, Forschung, Begutachtung

Asphalt, Beton, Bitumen, hydraulische Bindemittel, Gesteinskörnungen, RC-Baustoffe, industrielle Nebenprodukte, Bauschutt, Böden

RAP-Stra-Anerkennungen:

	A	B	C	D	G	H	I
0				D0			
1	A1		-		G1	H1	I1
2		-	-		G2		I2
3	A3 A4	B3 B4	- -	D3 D4	G3 G4	H3 H4	I34 I4

Betonprüfstelle (VMPA-B-2001)

Prüf-, Überwachungs- und Zertifizierungsstelle für Beton nach BayBO (Kennziffer BAY14)

Überwachungs- und Zertifizierungsstelle für Gesteinskörnungen und Asphalt gemäß BauPG (Kenn-Nr. 1280)

Mitglied im Bundesverband unabhängiger Institute für bautechnische Prüfungen e.V.

11.11.2010 DMS

Technical Report No. 2010-B1-I

Laboratory Investigations on tecRoad®- Modified Asphalt with Aggregates from Libya

1. Introduction

In December 2009, a meeting took place at the office of Institute Dr.-Ing. Gauer Ingenieur-GmbH, in Regenstauf, Germany. Attending parties were technicians from COMPANY 1, TecRoad and Dr. Schmalz from IFB Gauer. Main issue was the use of tecRoad to enhance asphalt properties for the base- and wearing course of a certain road in Libya.

Aggregate-Samples were brought to the Laboratory of IFB Gauer from two different Quarries.

In a special program, the properties of the modified asphalt were tested. In a comparative study, base course specimen with normal, non modified bitumen and wearing course specimen with tecRoad -modified bitumen were tested regarding the stability and the low temperature behaviour. Included in the study were also asphalts modified with a product called Thermoplast.

This is a report of the test conditions and the test results.

2. Abstract

The test program was set up to show the improvement of asphalt properties by using tecRoad. Tests were carried out according to German and European Standards, to show the high temperature stability and the improved low-temperature behaviour. One of the questions was which aggregate source ("Quarry" or "New Material") delivers better quality with special regard to bitumen absorbency.

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The tests were carried out with laboratory prepared asphalt with gradation curves similar to the one used in Libya. Beside this, the use of natural sand was tested.

The results of the tests with tecRoad modified laboratory mixed asphalt show certain benefits compared to the asphalt modified with a thermoplastic modifier.

As a conclusion, it can be said, that the modification with tecRoad enhances the properties of asphalt in the high and low temperature range. It is well known, that rubber modification improves stability and cracking susceptibility and ameliorates the water susceptibility. Even in insufficient compacted asphalts, the benefits of the tecRoad-modification can be seen and measured.

As a consequence, the tecRoad-modification together with a good mix design and a thorough laying and compacting gives high quality durable asphalt which meets the special demands of a road in a desert climate. And, what is more, the tecRoad-modification is able to compensate unavoidable deviations in materials, preparation, laying and compaction of the asphalt.

3. Scope

In a first step, several mix designs had to be tested. The following parameters had been varied:

- Layer: Asphalt for base-course and asphalt for wearing course
- Source of aggregates: "quarry" or "new source"
- The kind of sand: crushed sand or natural sand
- The Additive: tecRoad and Thermoplast

The aim of the investigation was to specify the mix design for at least four different asphalt mixes, either base-course and wearing course using both sources of aggregates.

After the mix design, an additional test program was set up to show the improvement of asphalt properties by using tecRoad to modify the asphalt used for wearing courses in a desert climate. It is well known, that the addition of rubberised bitumen has the following advantages:

- Increased bonding capacity
- Increased heat and deformation resistance
- Improved low-temperature behaviour
- A slowing-down of the ageing process

To validate the improvements in low and high temperature conditions, a comparative study was executed.

The following standardized test methods for hot mix asphalt were used:

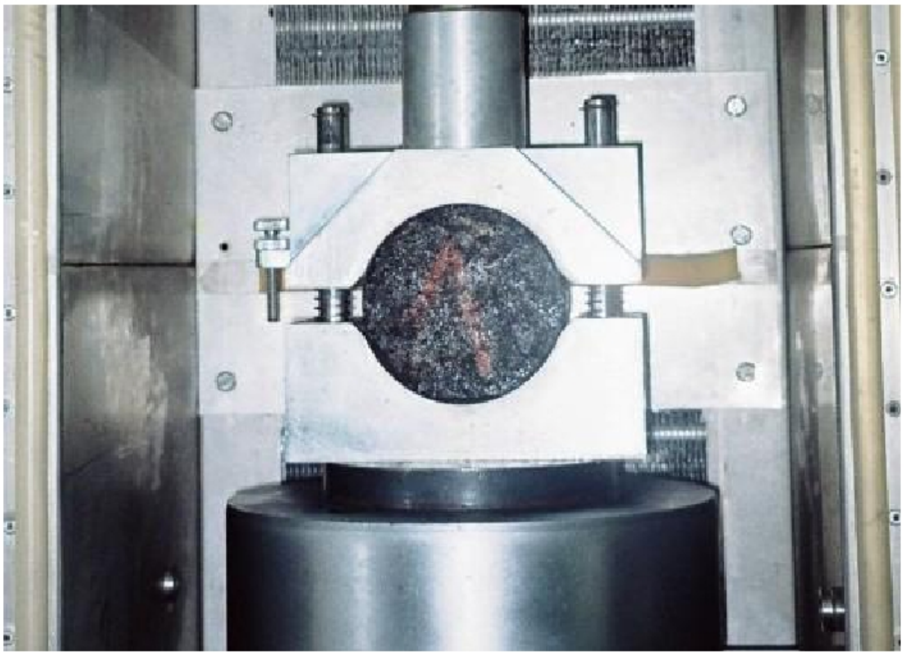


Fig. 1: EN 12697-30 Marshall-Test Stability, Flow and Marshall Quotient Value

Fig. 2: prEN 12697-44 3-Point-Bending-Test, Crack propagation, low temperature behaviour

The specimen for Three-Point-Bending test were preparated according to EN 12697-33, Slab Compactor.

All tests were carried out with specimen from asphalt mixed in laboratory.

4. Aggregates

4.1 Density and Gradation of delivered Aggregates

The following aggregates were delivered by COMPANY 1:

Sample Nr.	**Type**	**Product Size** [mm]	**delivered** [kg]	**Density** g/cm³
N1	Natural Sand Libya		55	2,643
V1	New Material	0/5	55	2,732
V2	New Material	5/14	35	2,708
V3	New Material	14/20	45	2,711
V4	New Material	20/25	36	2,710
Q1	Quarry	0/5	50	2,707
Q2	Quarry	5/14	36	2,673
Q3	Quarry	14/20	42	2,628
Q4	Quarry	20/25	45	2,611

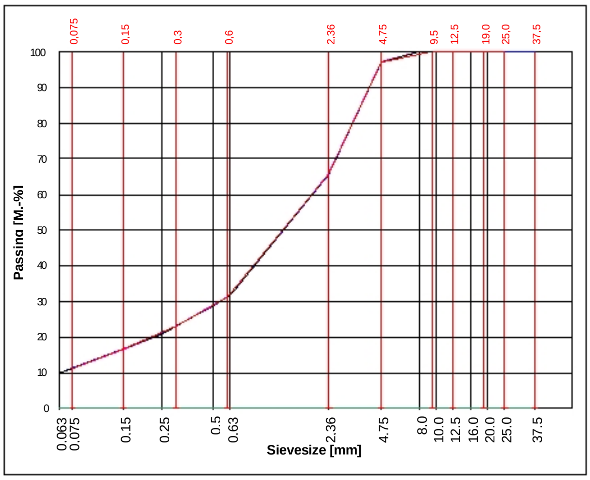
Table 1: Delivered Aggregates

For mixing purposes the aggregates with a product size of 0/5 mm were fractionated in two parts, one part with the size of 0/2,36 mm and the second part with the size of 2,36/5 mm.

Sample Nr.	**Type**	**Product Size** [mm]	**Density** g/cm³
V1A	New Material	0/2,36	2,732
V1B	New Material	2,36/5	2,732
Q1A	Quarry	0/2,36	2,707
Q1B	Quarry	2,36/5	2,707

Table 2: Aggregates after fractionation

The gradation curve of every single sample was determined. The gradation curves are plotted in figures 3 to 17. To get complete information, two different sets of sieves have been used. Red lines and red numbers show the ASTM-sieve set.



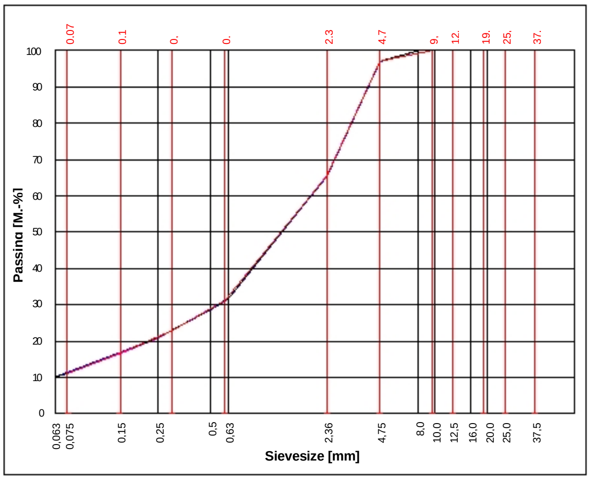
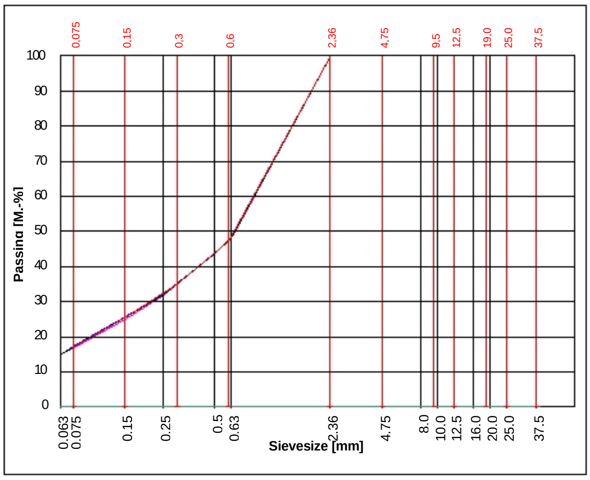


Fig. 5: Gradation of Natural Sand, N1 Fig. 6: Gradation of New Material 0/5, V1



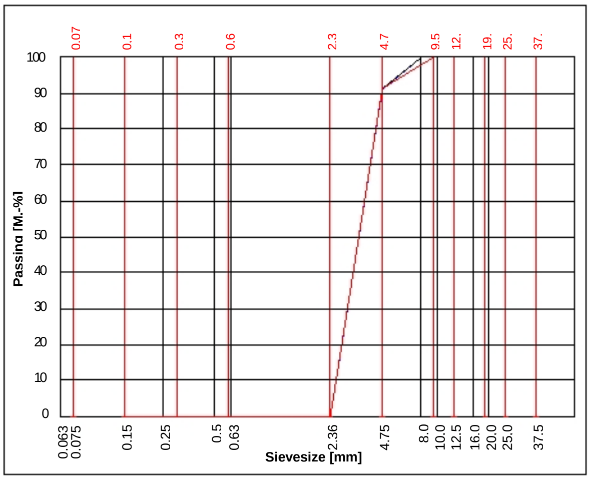
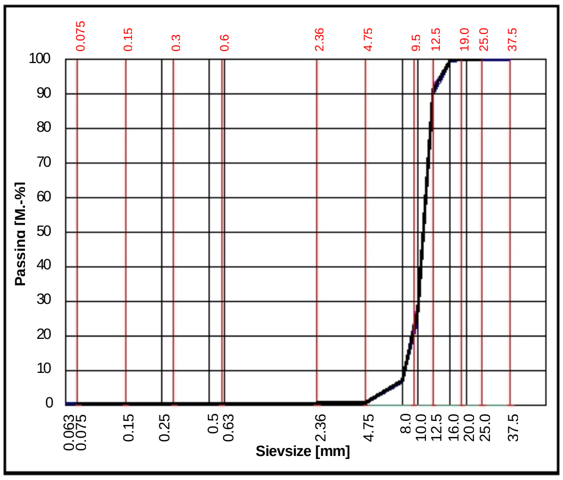


Fig. 7: Gradation of New Material 0/2,36, V1A Fig. 8: Gradation of New Material 2,36/5, V1B



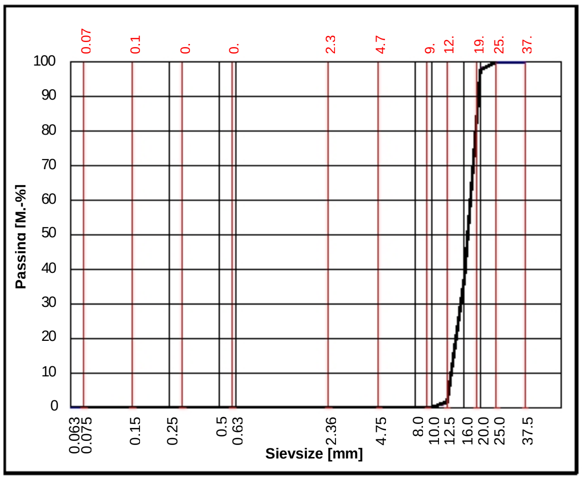


Fig. 9: Gradation New Material 5/14, V2 Fig. 10: Gradation Curve of New Material 14/20, V3

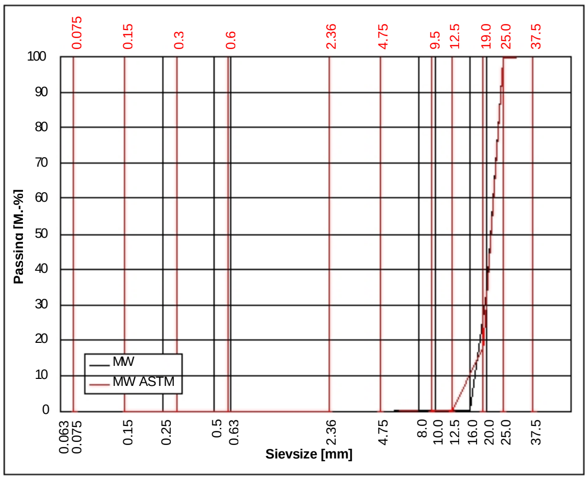
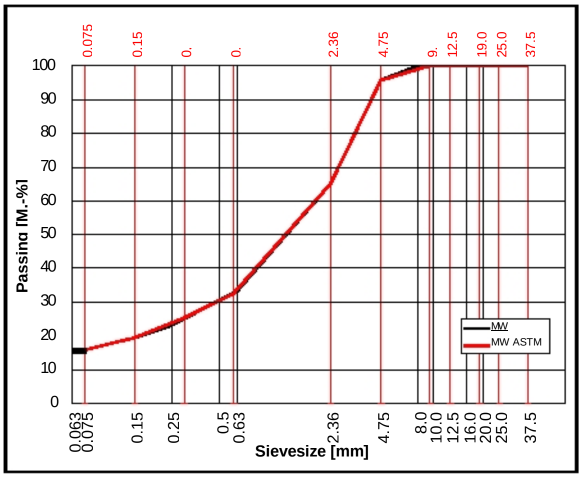


Fig. 11: Gradation Curve of New Material 20/25, V4



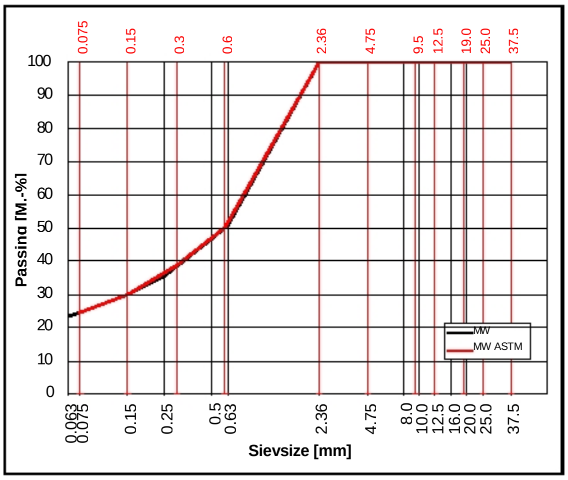
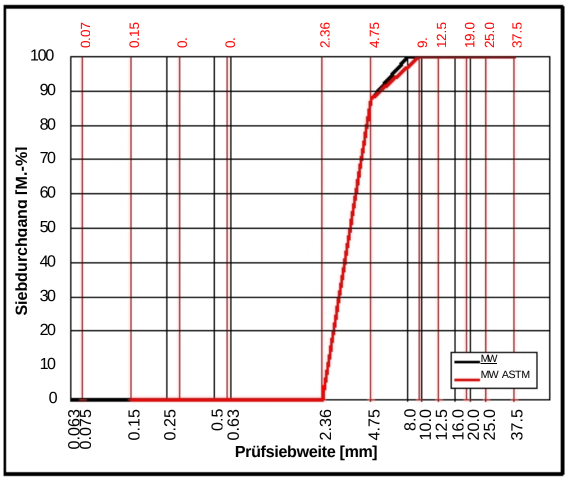


Fig. 12: Gradation of Quarry Material 0/5, Q1 Fig. 13: Gradation Quarry Material 0/2,36, Q1A



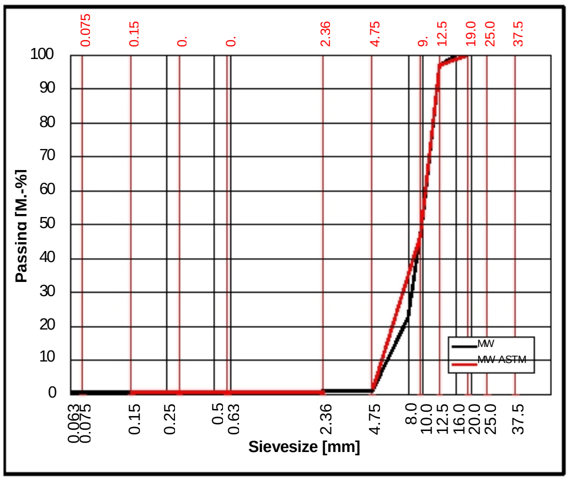


Fig. 14: Gradation Quarry Material 2,36/5, Q1B Fig. 15: Gradation Quarry Material 5/14, Q2

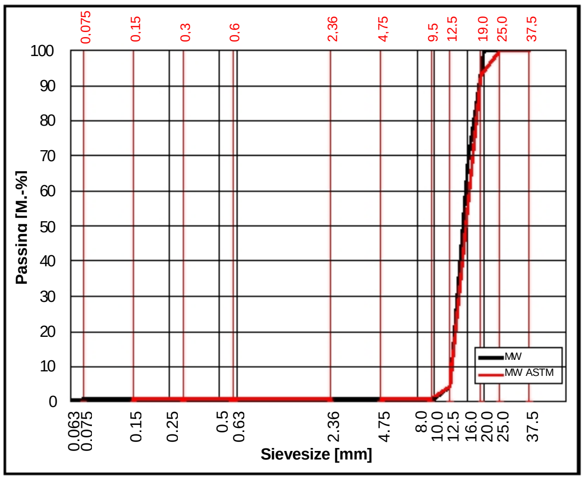


Fig. 16: Gradation Quarry Material 14/20, Q3

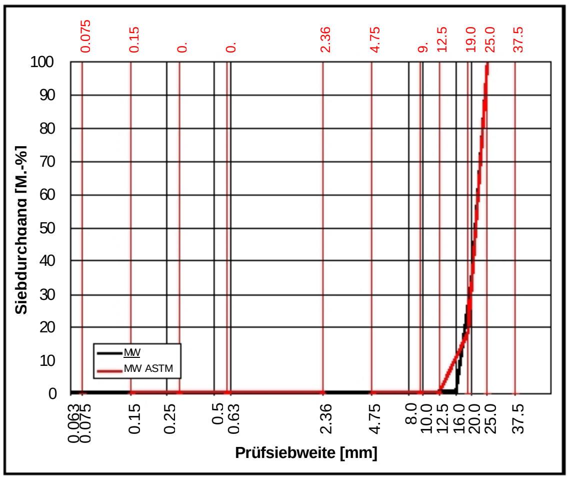


Fig. 17: Gradation Quarry Material 20/25, Q4

4.2 Gradation Curves

4.2.1 Special Specifications for Wearing Course

COMPANY 1 is planning to use the following specifications for the gradation of the of asphalt concrete wearing course.

COMPANY 1 - Specifications for Wearing Course			
Sieve Size		**Percentage passing**	
		lower	upper
Inch	mm	M.-%	M.-%
1	25,0	100	
3/4	19,0	100	
1/2	12,5	---	
3/8	9,5	75,0	85,0
No. 4	4,75	50,0	58,0
No. 8	2,36	30,0	38,0
No. 30	0,6	12,0	20,0
No. 50	0,3	7,0	15,0
No. 100	0,15	3,0	11,0
No. 200	0,075	3,0	8,0

Table 3: Gradation Specification for WC

Air voids in asphalt mixture: 3 - 5 %

Voids filled by bitumen: 65 - 80 %

Marshall Stability: min. 600 kg

Marshall Flow: 2 - 4 mm

4.2.2 Wearing Course with New Material

Using the New Material, the following gradation was received. With the New Material it was possible to get a gradation within the special specification of COMPANY 1, without fractionating any particle size class.

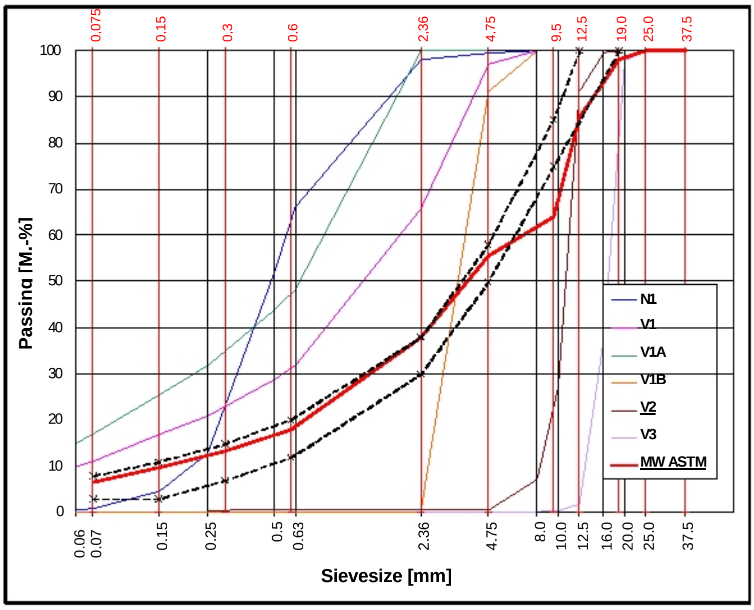


Fig. 18: WC 0/19 with New Material

The suggested Job Mix Formula is given in table 4, figure 19 shows the gradation curve obtained.

No.	**Supplier**	**Size**	**Admixture**
		mm	M.-%
1	New Material	0/5	57
2	New Material	5/14	31 12
3	New Material	14/20	

Table 4: JMF for WC - New Material

The binder content was 5,9 M.-%.

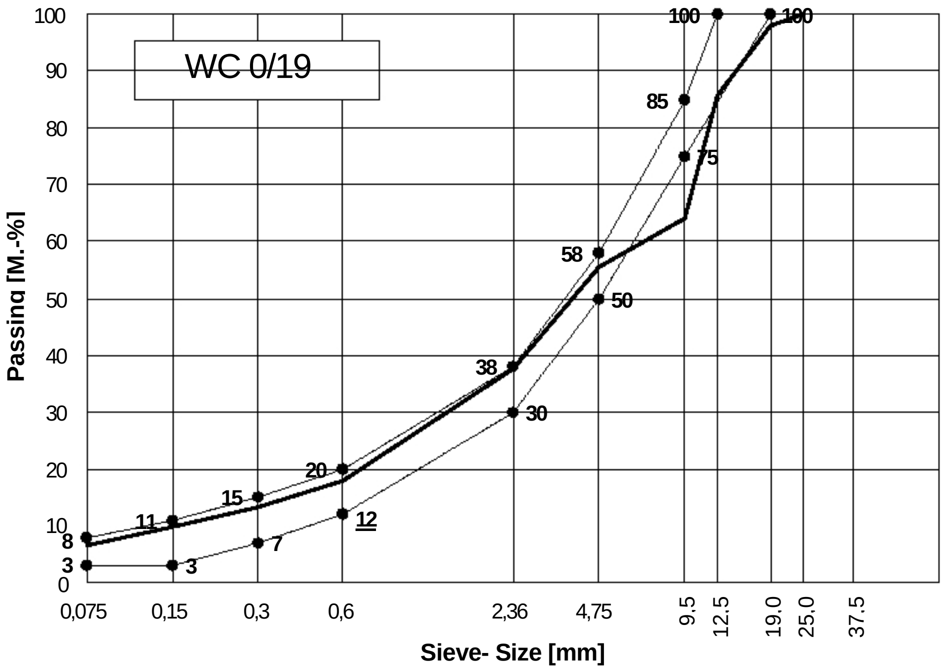


Fig. 19: WC 0/19 with New Material

4.2.3 Wearing Course with Quarry Material

Using the material from the Quarry, the following gradation was received. With the Quarry-Material it was possible to get a gradation within the special specification of COMPANY 1.

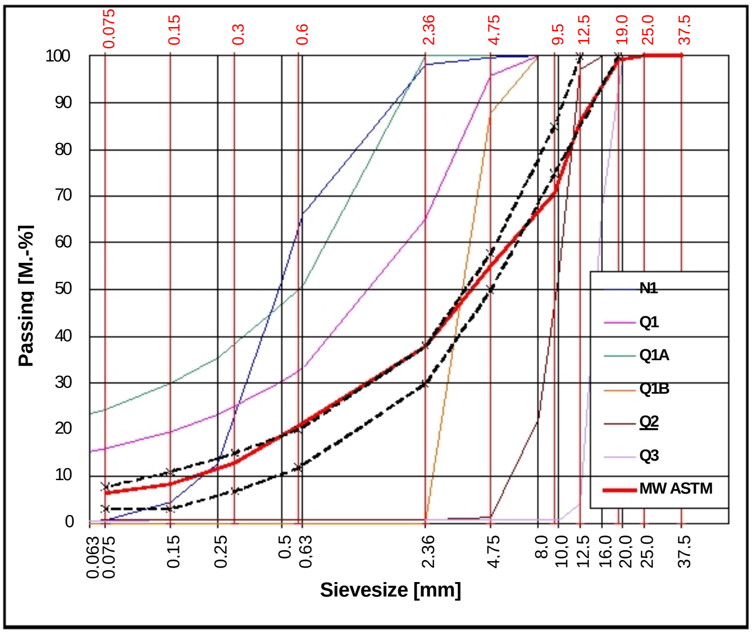


Fig. 20: WC 0/16 with Quarry Material

The suggested Job Mix Formula is given in table 5, figure 21 shows the gradation curve obtained.

No.	Supplier	Size	Admixture
		mm	M.-%
1	Natural Sand	0/2	13
2	Quarry	0/2,36	25 **3**
	Quarry	2,36/5	19 **5**
	Quarry	5/14	29 **5**
	New Material	14/20	14

Table 5: JMF for WC - Quarry Material

The binder content was 6,4 M.-%.

To reduce the amount of absorptive aggregates, a part of the 0/2,36 mm fraction was replaced by natural sand.

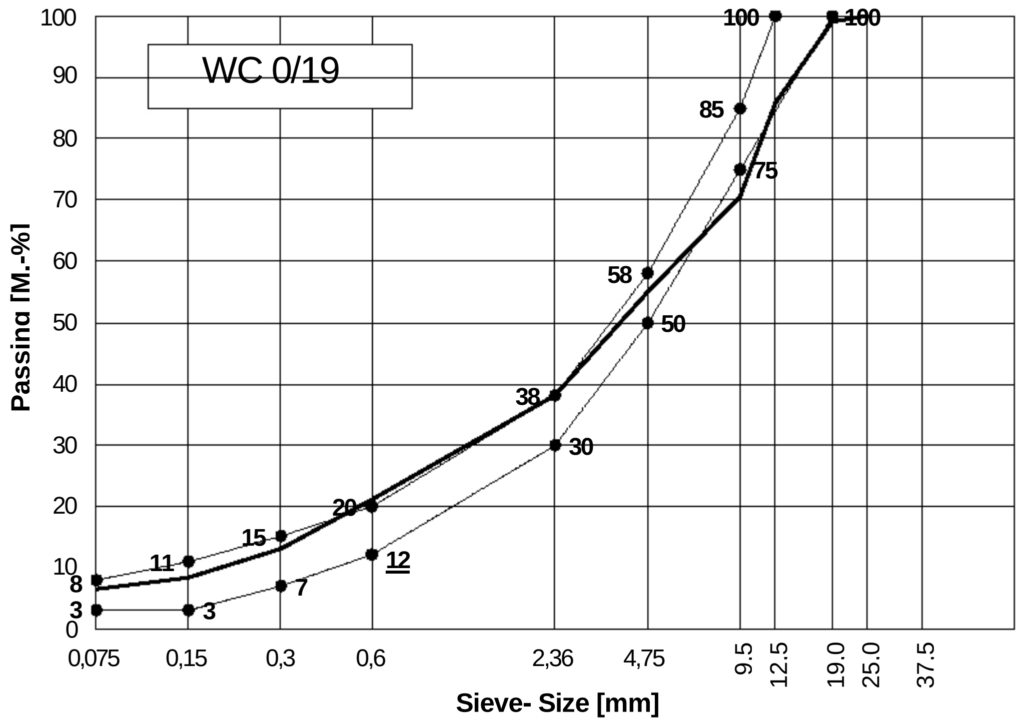


Fig. 21: WC 0/19 with Quarry Material

4.2.4 Special Specifications for Binder Course

COMPANY 1 is planning to use the following specifications for the gradation of the asphalt concrete Binder Course, BC.

COMPANY 1 - Specifications for Base Course			
Sieve Size		Percentage passing	
		lower	upper
Inch	mm	M.-%	M.-%
1	25,0	100	
3/4	19,0	75	100
1/2	12,5	---	
3/8	9,5	45	70,0
No. 4	4,75	30,0	50,0
No. 8	2,36	20,0	35,0
No. 30	0,6	8,0	20,0
No. 50	0,3	4,0	14,0
No. 100	0,15	2,0	10,0
No. 200	0,075	1,0	8,0

Table 6: Gradation Specification for BC

Air voids in asphalt mixture: 3 - 8 %

Voids filled by bitumen: 66 - 75 %

Marshall Stability: min. 600 kg

Marshall Flow: 2 - 4 mm

4.2.5 Binder Course with Quarry Material

4.2.5.1 COMPANY 1 Specifications

Base Course was merely tested with the material from the Quarry. The following gradation was received. With the Quarry-Material it was possible to get a gradation within the special specification of COMPANY 1.

To avoid to exceed the fines ((No. 200), natural sand was used to replace a part of the crushed sand 0/5 (Q1). This helps also to reduce the amount of absorptive aggregates.

The binder content was 5,2 M.-%.

The obtained Job Mix Formula is given in Table 7 and fig. 22.

No.	Supplier	Size	Admixture
		mm	M.-%
1	Natural Sand	0/2	10
2	Quarry	0/2,36	20
3	Quarry	2,36/5	13
4	Quarry	5/14	33
5	Quarry	14/20	18
6	Quarry	20/25	6

Table 7: JMF for BC with Quarry material and natural sand

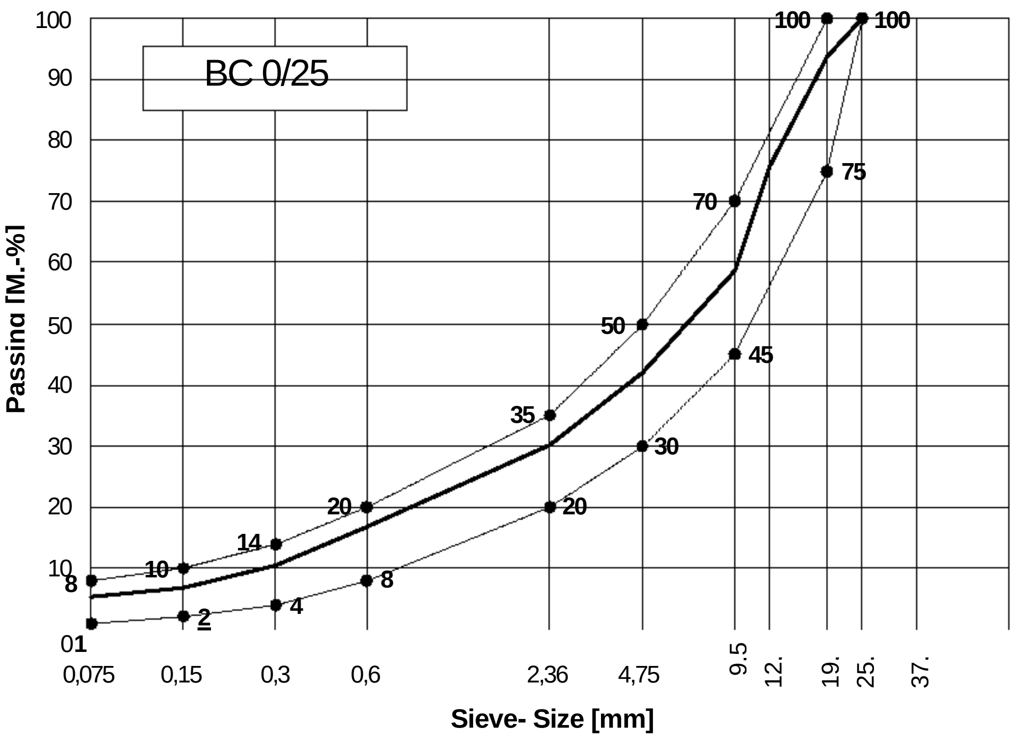


Fig. 22: BC 0/25 with Quarry material and natural sand

4.2.5.2 IFB Gauer Suggestion

With the aggregates, it is probably possible to change the gradation curve of the Binder Course towards a coarser particle size distribution. With this more coarse material it should be possible to save bituminous binder and enhance the thickness of the base layer.

The binder content can probably be reduced to 5,0 M.-%.

The suggested Job Mix Formula is given in Table 8, the gradation curve is shown in figure 23.

No.	Supplier	Size	Admixture
		mm	M.-%
1	Natural Sand	0/2	10
2	Quarry	0/5	31 25
3	Quarry	5/14	17 17
4	Quarry	14/20	
5	Quarry	20/25	

Table 8: JMF for Coarse BC

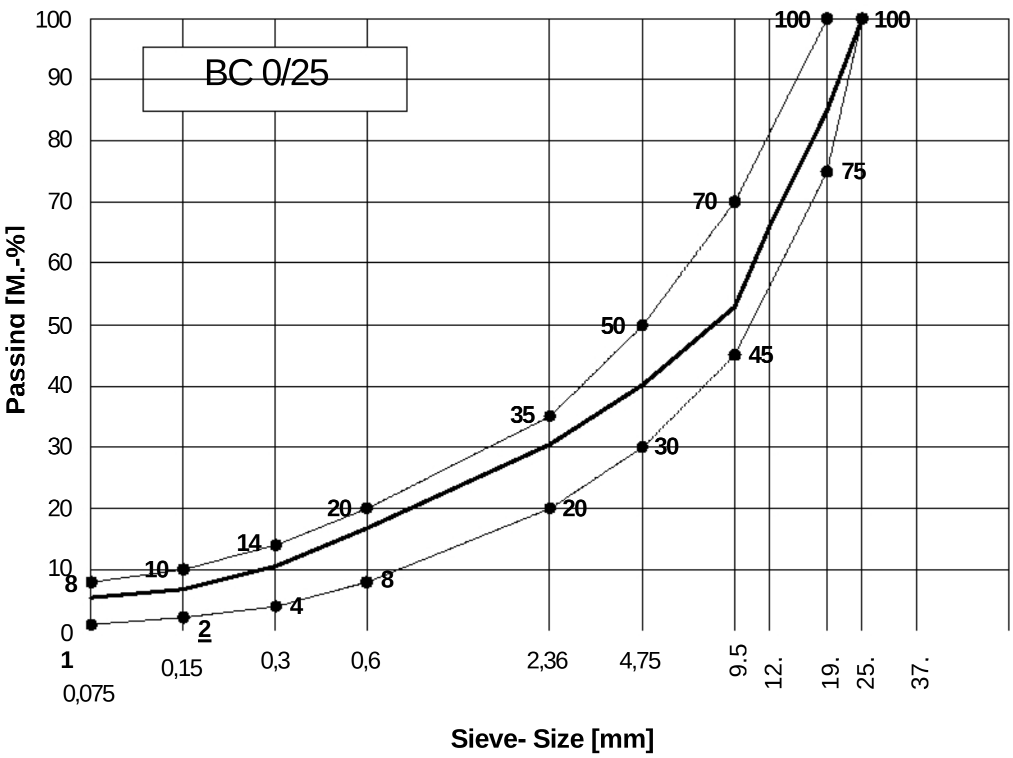


Fig. 23: Suggested Coarse BC 0/25 with Quarry material and natural sand

4. Preparation of Specimen

The asphalt mix design was following the specification of the one that is used in Libya. The bitumen was a penetration grade bitumen 60/70, which was brought from Libya.

For the asphalt mix design of the binder and wearing course COMPANY 1 gave information about gradation curves that were used in some previous tests (see special specifications in chapter 4.2.1 and 4.2.4).

With a chosen gradation curve and different amounts of binder several asphalt mixes have been produced and examined.

For the fabrication of the asphalt, a laboratory mixer (Fig.24) according to DIN EN 12697-35 (Bituminous mixtures-Test methods for hot mix asphalt Part 35: Laboratory mixing) was used.

After mixing at a temperature of 170°C, Marshall-specimen and slabs according to DIN EN 12697-35 (Bituminous mixtures - Test methods for hot mix asphalt - Part 33: Specimen prepared by roller compactor) were prepared. The laboratory roller compactor of the Institute Dr.-Ing. Gauer is shown in figure 25.

Fig.24: Laboratory Mixer acc. to DIN EN 12697-35

Fig. 25: Laboratory Roller Compactor according to DIN EN 12697-35

With this equipment, it is possible to produce specimen in the laboratory with nearly similar properties than the one of asphalt layers on the road. The result of the laboratory preparation is dense asphalt concrete as it is recommended by the standards and the generally accepted technical rules. From the compacted slabs, cores with a diameter of 150 mm were drilled. The cores were cut in two halfs to get the specimen for the 3-Point Bending Test (see figure 2).

5. Test Results

5.1 Wearing Course

5.1.1 WC-Asphalt with New Material

Table 9 shows the variation matrix of the asphalt mixes.

For the studies, we used bitumen with penetration grade 60/70, which was brought from Libya. The asphalt was mixed in accordance to figure 19, the binder content was 5,9 M.-%

The amount of tecRoad of 8 % is part of the binder content. The amount of Thermoplast of 6 % is additional.

1	Wearing Course	1	New Material	1	tecRoad
2	Base Course	2	Quarry (Old)	2	Thermoplast

Table 9: Variations matrix for WC

Table 10 shows the results of the test on Marshall-specimen and the cores taken from the roller compacted slabs. Figures 26 and 27 show the graphics of the results.

WC - Marshall Specimen with „New Material"					
No.	**Type**	**Void Content** Vol.-%	**Bulk Density** g/cm³	**Stability** kN	**Flow / Strain** mm / ‰
111	**tecRoad**	4,8	**2,371**	**15,5**	**3,5**
112	Thermoplast	3,3	**2,404**	**14,5**	**3,5**
Three Point Bending Test					
111	**tecRoad**	6,3	**2,277**	**11,4**	
112	Thermoplast	5,4	**2,355**	**9,5**	

Table 10: WC with New Material, Test Results

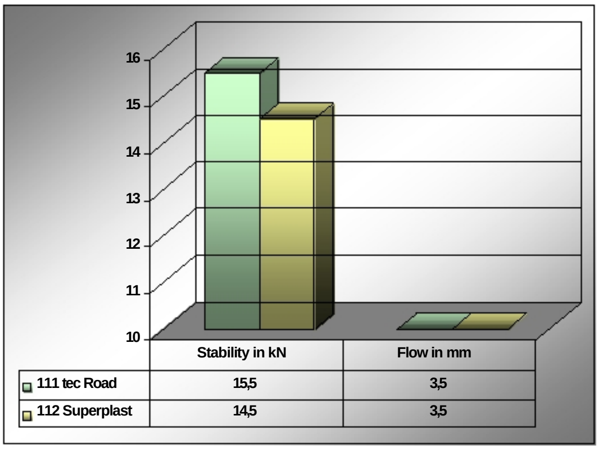


Fig. 26: WC, New Material, Marshall-Test Results

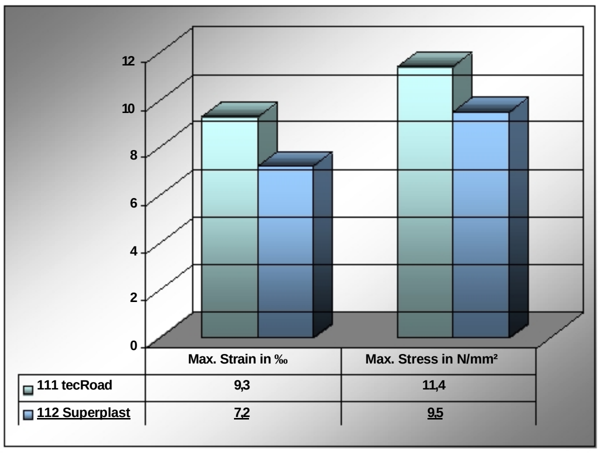


Fig.27: WC, New Material, 3-Point Bending Test

5.1.2 WC-Asphalt with Quarry Material

1	Wearing Course	1	New Material	1	tecRoad
2	Base Course	2	Quarry (Old)	2	Thermoplast

Table 11: Variations matrix for WC

The asphalt was mixed in accordance to figure 21, the binder content was 6,4 M.-%.

The amount of tecRoad of 8 % is part of the binder content. The amount of Thermoplast of 6 % is additional.

Table 12 shows the results of the test on Marshall Specimen and the cores taken from the roller compacted Slabs. Figures 28 and 29 show the graphics of the results.

WC - Marshall Specimen with Aggregates from the Quarry					
No.	**Additive**	**Void Content** Vol.-%	**Bulk Density** g/cm³	**Stability** kN	**Flow / Strain** mm / ‰
121	**tecRoad**	5,1	**2,317**	**15,0**	**3,4**
122	Thermoplast	4,6	**2,325**	**14,5**	**3,5**
Three Point Bending Test					
121	**tecRoad**	6,6	**2,277**	**10,8**	
122	Thermoplast	5,5	**2,355**	**9,1**	

Table 12: WC with Material from Quarry, Test Results

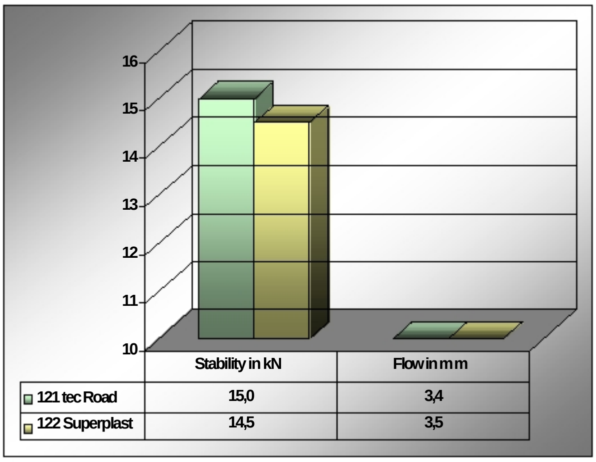


Fig. 28: WC, New Material, Marshall-Test Results

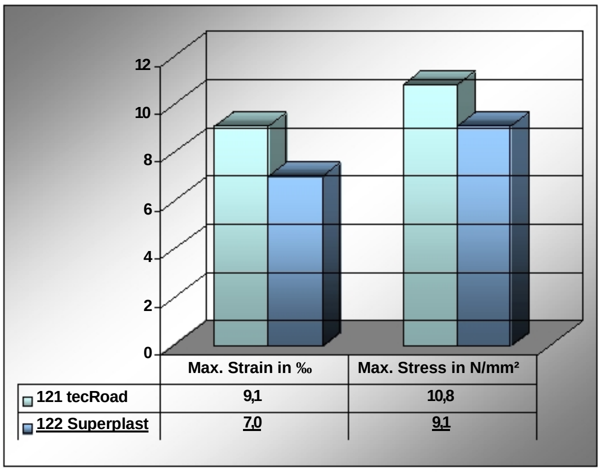


Fig. 29: WC, New Material, 3-Point Bending Test

5.2 Binder Course

5.2.1 BC-Asphalt with Material from the Quarry

Table 13 shows the variation matrix of the asphalt mixes.

For the studies, we used bitumen with penetration grade 60/70, which was brought from Libya. The binder content was 5,2 M.-%.

1	Wearing Course	1	New Material	1	tecRoad
2	Base Course	2	Quarry (Old)	2	Thermoplast
				3	Bitumen 60/70

Table 13: Variations matrix for BC

Table 14 shows the results of the test on Marshall Specimen and the cores taken from the roller compacted slabs. Figures 21 and 22 show the graphics of the results.

BC - Marshall Specimen with Aggregates from the Quarry					
No.	**Additive**	**Void Content** Vol.-%	**Bulk Density** g/cm³	**Stability** kN	**Flow / Strain** mm / ‰
223	**none**	**5,2**	**2,313**	**12,5**	**3,3**

Table 14: Variations matrix for BC - Test Results

With the suggested coarse gradation curve no test could be done because of lack of aggregates. We suggest, doing some trials in the asphalt plant.

6 Conclusions

To show the improvements of asphalt properties by using tecRoad for modifying asphalt, different tests were carried out according to German and European Standards. The tests were carried out with laboratory prepared asphalt in the specification range of special gradation curves, which were given by COMPANY 1.

The results of the test with tecRoad modified laboratory mixed asphalt show certain benefits compared to the asphalt with Thermoplast

- higher stability
- higher tensile strength in the 3-Point Bending Test at 0 °C

The results of the tests show the increased high temperature stability and the improved low-temperature behaviour of the tecRoad-modified asphalt.

The results of the tests with two sources of aggregates are to be seen in a differentiated manner:

The material from the Quarry is more absorptive than the New Material. This leads to higher binder content. In the tests the Quarry aggregates needed 0,5 M.-% more binder to receive comparable properties than the asphalt made with New Material.

In general, a lower void content leads to higer stability and higher tensile strength. Because of the higher viscosity of the tecRoad modified binder, the void content of the specimen with tec-Road is also higher than the one of the specimen with Thermoplast. An optimized mix design with a comparable void level will encrease the performance of the tecRoad-modified asphalt.

A small amount of around 10 % of natural sand can replace a part of the absorptive fraction. This means that the aggregates 0/5 have to be fractionated in 0/2,36 and 2,36/5.

If there is the possibility to enhance the thickness of the base layer, the Binder Course can be produced with more coarse material. This also would save bituminous binder.

We suggest mixing some binder and wearing course asphalts in accordance to the Job Mix Formulas in this report in order to find out, whether the laboratory results can be obtained in field production. The results should be compared with the results in the report and - if necessary - an optimisation should be carried out.

We recommend the use of tecRoad to enhance the quality of asphalt for desert roads in Libya.

INSTITUT DR.-ING. GAUER
Ingenieurgesellschaft mbH

Dr.-Ing. M. Schmalz