Budapest University of Technology and Economics
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Summary of Doctoral Dissertation

Behavior of grids in asphalt pavement structures

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1. Introduction and purpose of the dissertation

Important changes happened lately in reinforcement of asphalt not only in Hungary, but also in Europe. New materials and technology innovation has appeared searching for best practice in methods for avoiding errors in the asphalt pavement. New material and technology help the development of the asphalt pavement quality, in order to reduce the risk of error in the implementation methods. In the last decade, the era of build in net has commenced.
During this period different type and quality of net was built into all asphalt reconstructions all around the country. This work was carried out, without any technological experience and quality control regarding the implementation. Recently more and more errors had been registered at pavement with build in net and also new laboratory researches has been made to map all characteristics of build in nets.
The purpose of this study is to make a clear understanding about the pros and cons of net reinforcement in asphalt, and to make a proposal about the implementation methods and it's effect on the environment. At various locations using net is possible and at several others the usage of net is forbidden.

In this dissertation, I want to clarify conceptual confusions about grids and nets applying in asphalt pavements structures, define the repairing and –in some cases- damaging effect of grid usage. The biggest question in reinforcement of pavement is the possibility of mixture of grid and net with the asphalt layer below. To observe these attributes we used the three methods: slide method, drag experiment and Leutner Test. Small and large wheel observations have been made to research track appearances in fortified construction. The lifetime of the construction have been observed by a fatigue method: the standard four point bending method and master curve of the structure. The computer limited number model have been used to prove fatigue results, and with the adequate material model development used at different type of asphalts showed how gross asphalt can be replaced by the nets and grids usage.

- The application of the reinforcement is one of the most important aspect is the viewpoint of the role of cohesion. I determined that the quality and strength of cohesion using variety of process in the grid between the asphalt and the substrate with and without grids, and with texture-based composites.
- Some manufacturers also proposes to reduce the formation reinforcement of the riffle, but not supported exactly by research findings. Type of grids incorporating a large number of samples analyzed riffle formation of the asphalt.
- The grid building to the asphalt pavement will demonstrate the life-impact tests intended the increase of the extent the lifetime.
- Rigidity of the structure change is also considered important observation, because the effect may depend on the application of grid structure and the lattice stiffness and the size of the load and the applied temperature.
- Cracks formed in the cold thermal response, thermal cracks can also address the role of prevention research on.
- Using a computerized test I wanted to determine how thick the asphalt can be saved using fittings how large due to the replacement thickness.
- This research work also try to find answers to the question, what is the relationship of structure and state of the grid between the effect of use, and what physical and mechanical properties of the grid should be used in asphalt structures.

2. Scientific results of the dissertation, thesis

1. thesis

According to the mixture experiments (drags, slipping and Leutner shearing tests) I justified that applying grids or nets, effectiveness of the cohesion is decreased significantly. The tissue bearer materials produced the worst cohesion value because of the dividing effect of the nets. The applied asphalt grids with non bearer material can produce 60-90% of the cohesion values of the asphalt specimens without any strengthening material. In the case of the tissue bearer material that number is changed between 20-40%. The next picture shows the results of the drags and slipping test. [3] [4] [17]

I proved the above mentioned thesis with applying 109 tests. The next two images show the summarized results.
The first thesis was verified by carrying out the following tree types of test: test to drag, slip, and Leutner's Shearing test.
The test procedure for all three tests showed that a greater or lesser extent, the built in layers to the asphalt layers (texture-based material, steel grating grid) will downgrades the rate between the layers coherency.
The figure below shows the comparable, ie with the same asphalt, made from the same samples by incorporating types for drag-, and slip-test results were compared. The figure clearly shows the tendency that the grid-free samples are the best drag tensile strength and shear modulus value, followed by grids wireless carrier, and at the end of the line of upholstered carrier bars are located.

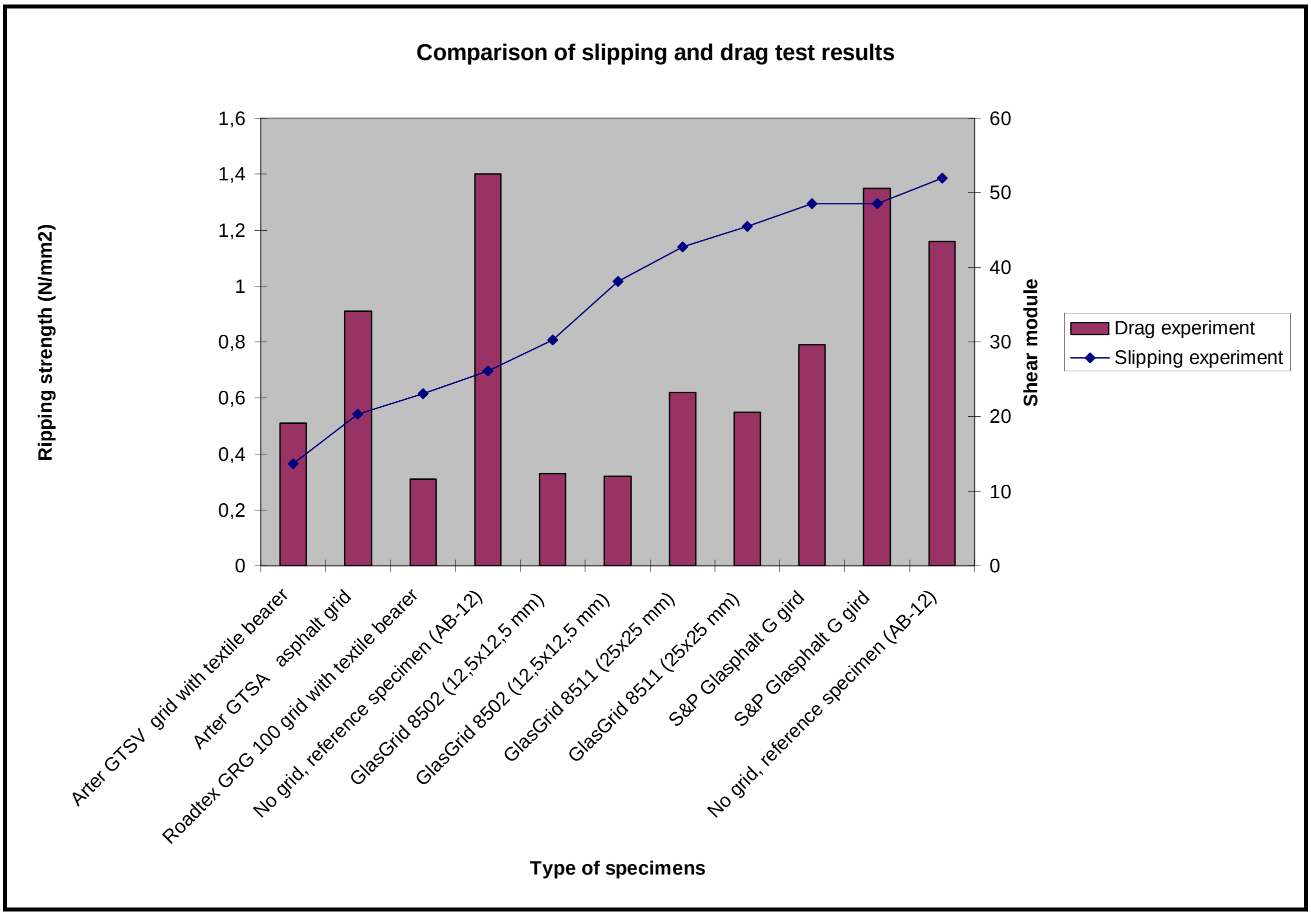

Image 1: Comparison of slipping and drag test results

I analyzed the difference of the results within the separate experiments the grids strengthened specimens.

I completed the analysis of investigating, how the different specimens containing implant, deviate from the reference model within the individual tests, ie the reference specimen results represent the percentage. In all three case analysis has been shown that the presence weakens the bars between the layers working together, also has been shown that the texture based substrate has a greater extent compared to grids without reducing working together.
I represented in the below image that specimens which had at least two results from two different test method.
The results clearly shown that the regardless of the type of test procedure, the reference, ie, textile grid specimens are the worst of the values (splitting power, tensile strength)

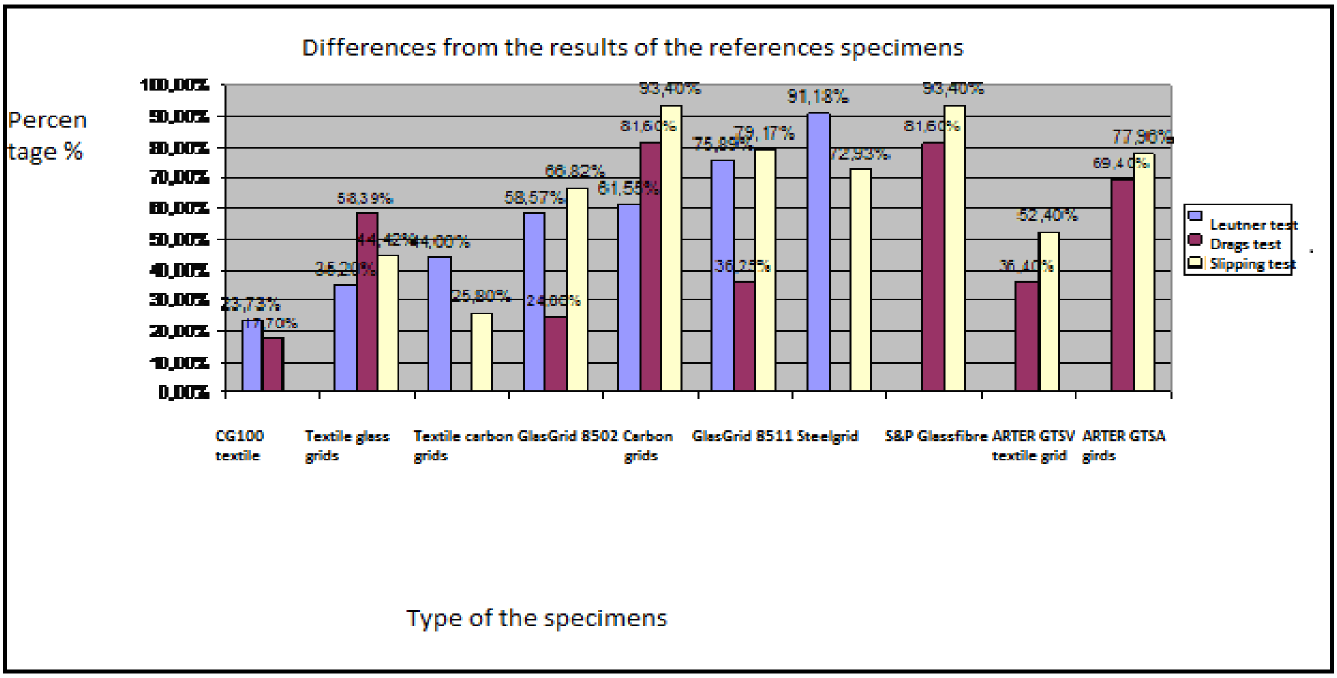

Image 2: Differences from the results of the references specimens

2. 1. thesis:

I proved after the long year's test observations showed that using asphalt grids in poor quality mixture can improve the rutting behavior of the structure. The results can be 40 % less than the reference, unreinforced (without grid) specimens values. Otherwise at the case of the mixture with better permanent deformation instinct – in Hungary signed F type mixture – the change is not standard. [3] [4] [17]

Using **Image 3**, it was analyzed the context of different types of grids compared with the test result from the incorporation of grid-implant differences. The analysis of each grids value and their deviations were taken into account in the analysis.

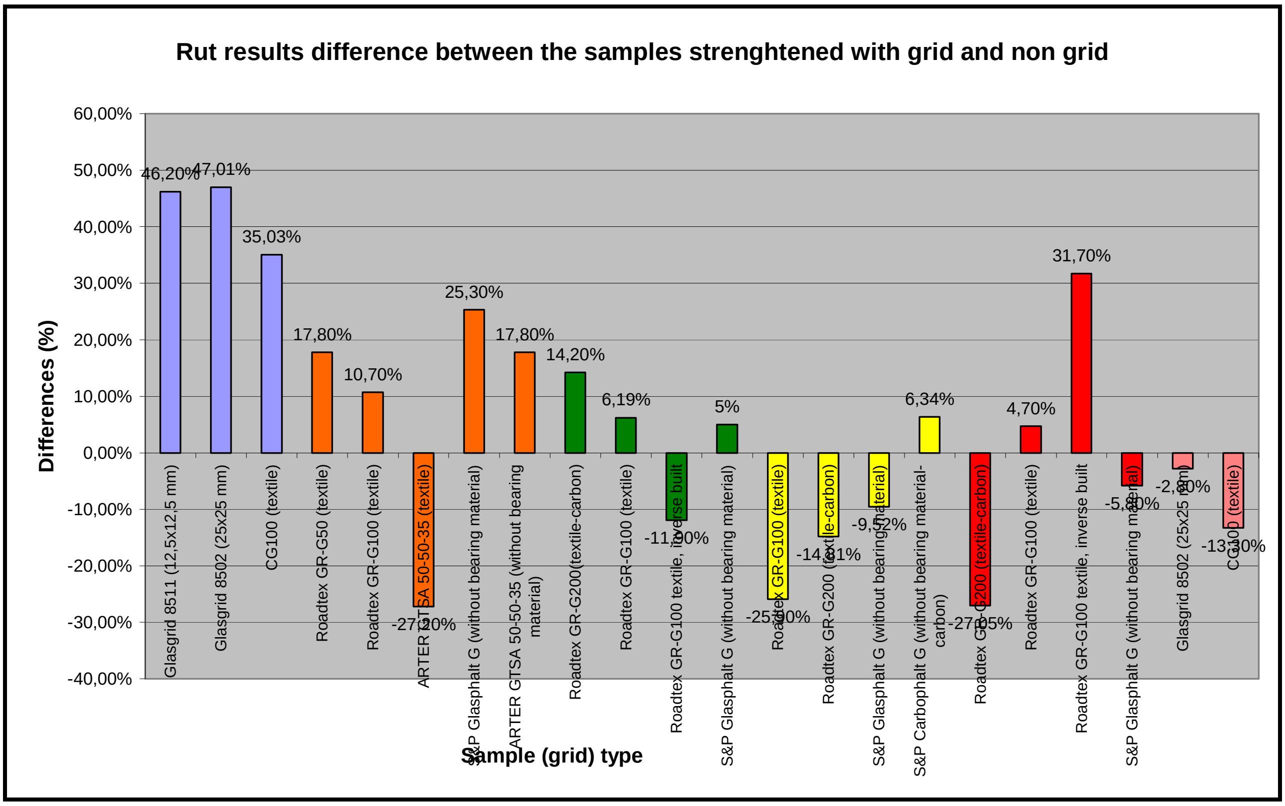

Image 3: Rut results difference between the samples strengthened with grids and non grids

I indicated with blue the difference AC-11 mixture from the reference specimen, AB-12 mixture with orange, AB-11 mixture with green, AB-11/F mixture with yellow, mAB-12/F with red and SMA-11/mF mixture colored with pink.

2.2 thesis

I also proved that applying the tissued net in asphalt reinforcement could produce worse results than the asphalt grids without a bearing material; we get less rutting results in that case. It can be see in the under mentioned picture. [3] [4] [17]

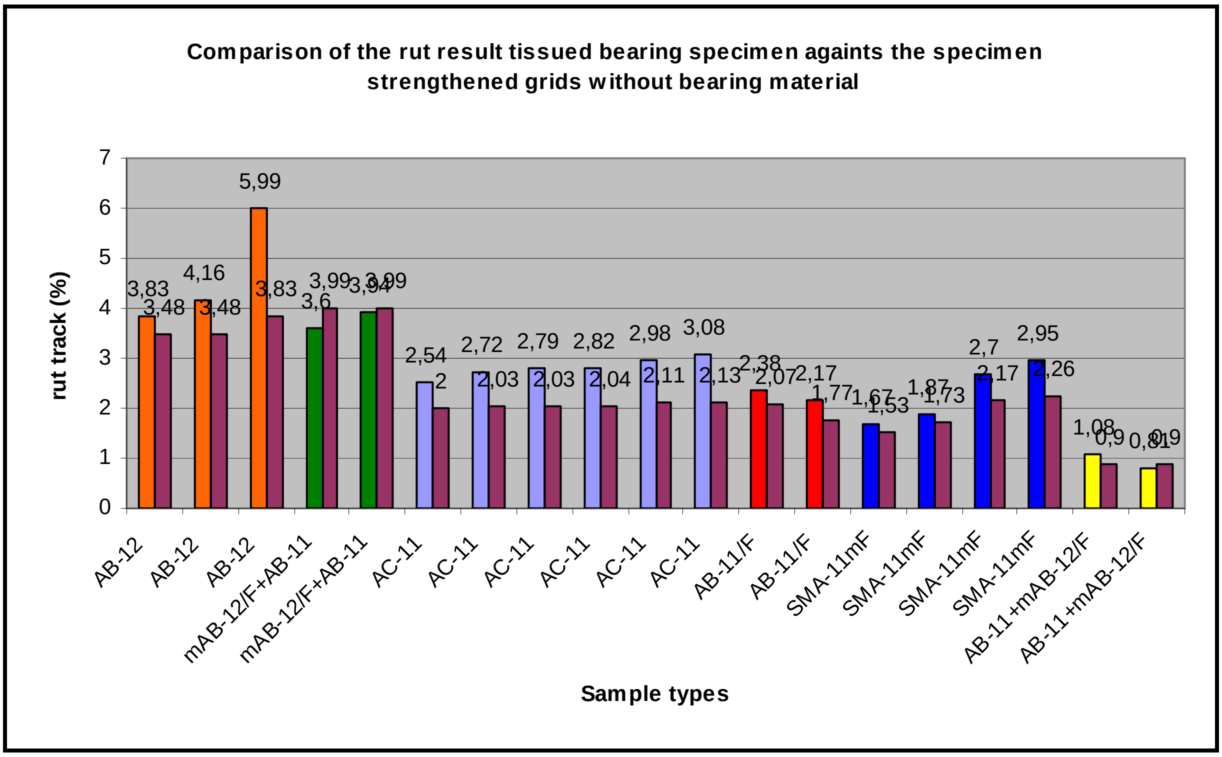

Image 4: Comparison of the rut result tissued bearing specimen against the specimen strengthened grids without bearing material

The results are clearly showed that the textile grids have higher rutting results, than the asphalt grids without a bearing material.

I indicated with different colors the different textile grids. (Orange: AB-12, Green: mAB-12/F+AB-11, Light blue: AC-11, Red: AB-11/F, Dark Blue: SMA-11mF Yellow: AB-11+mAB-12/F) The tissued nets results are tinted with different colors, but I did not use different color for the grids without bearing material.

3. thesis

I justified applying the 4 points bending beam test results that the tests made without net produced less stress and strain, and the fatigue lines reflect that net fortified materials durability and lifetime is raised. (5 % to 25 %)
[3] [4] [17]

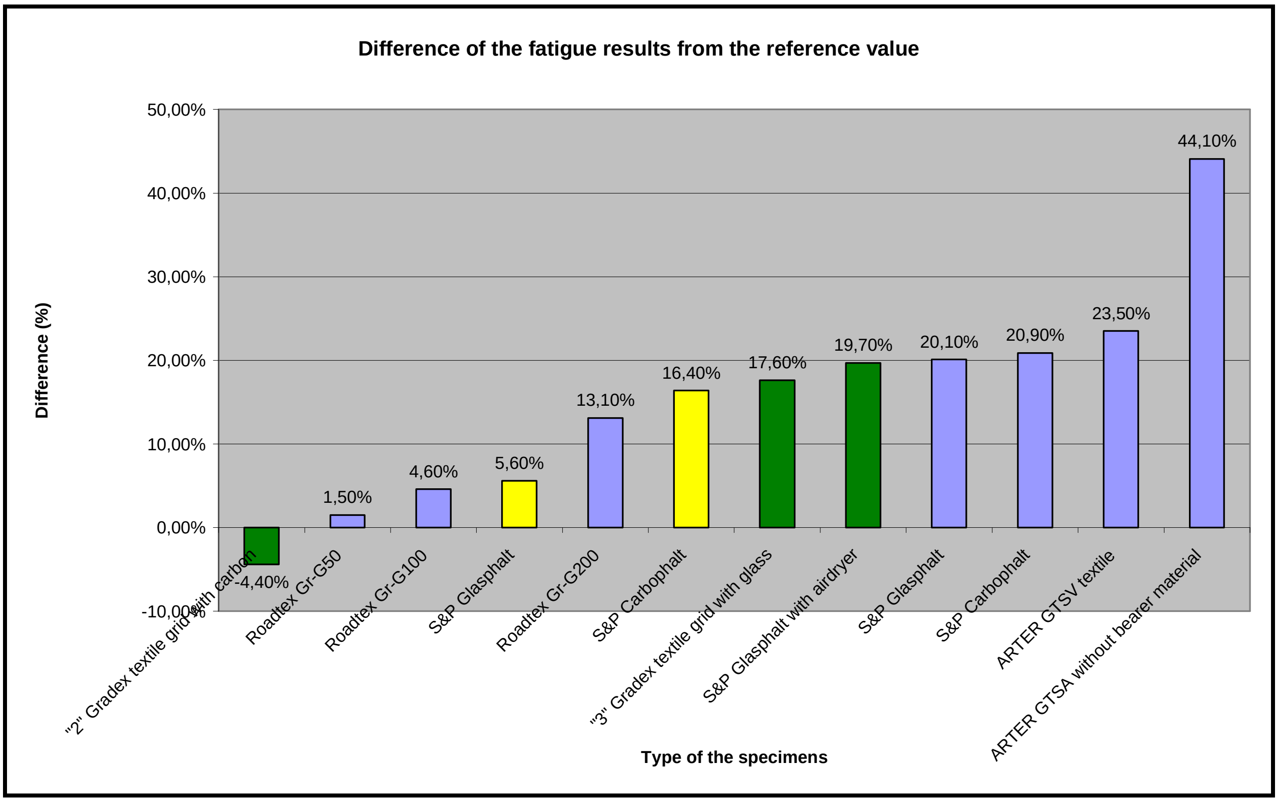

Image 5: Difference of the fatigue results from the reference value

The results show clearly that the tests made without net produced less stress and strain, and the fatigue lines reflect that net fortified materials durability and lifetime is raised. (5 % to 25 %). The result of the May 2004 test shows that tissued nets raise the results with only a few percent, but in other cases a serious 15% results appear. It is clearly visible that the nets without bearing materials are the most resistance to stress and strain. (At the image I colored with green the results of the AC-11 mixture, with yellow the results of the strain controlled AB-8 mixture and with blue the results of the stress controlled AB-12 mixture.)

4. thesis

With the creation of the master curves I could confirm that the stiffness of the asphalt structure increase at the higher frequency range for the benefit of the reinforced specimen. At medium frequency level the grid reinforced specimen has got same stiffness value like the unreinforced sample. [4] [5] [17]

The master curve is an appropriate tool to describe the behavior of the different asphalt mixtures. Different shift coefficients were used in this calculation. According to a Dutch method, the slope of the master curve determines the fatigue characteristic of the asphalt mixture. We can analyze the attitude of the asphalt at very special time and frequency range using master curve method and in this extreme condition we could not solve without it.

I used the sigmoid method to determine the shift coefficients. The next image shows the master curves of the grid strengthened and non grid specimens.

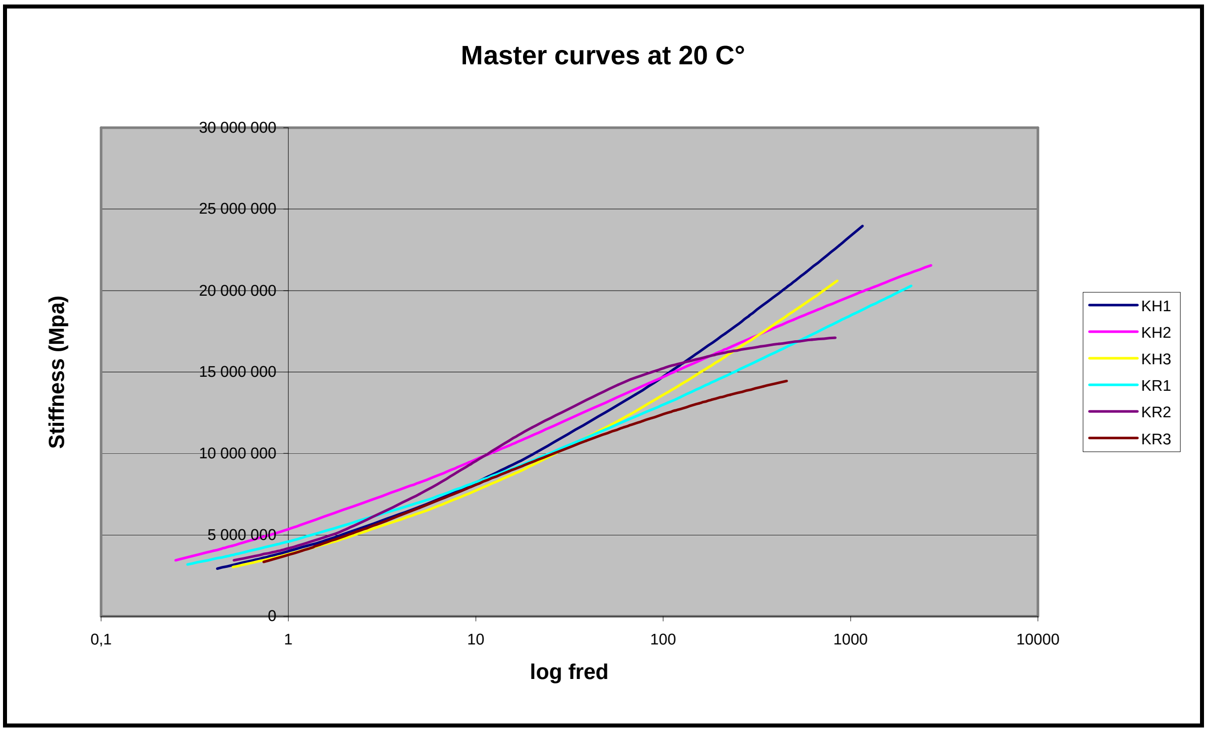

Image 6: Master curves of the non grid and grid strengthened specimens (KH: grid, KR: reference)

- All the master curves - and the grid reference is also made - in the medium frequency range (between 1 and 50 Hz) let approximately the same stiffness values.
- Observed low-frequency range to quickly decrease the rigidity of the asphalt, as attached to the grid samples.
- The higher frequency range, the viscous properties of asphalt otherwise, the load response will not shown an increase of stiffness than the elastic material with implant. As a result of these frequency ranges of the asphalt and the lattice stiffness ratio shifts in favor of the grid.
- The analysis of the master curves demonstrates that the other tests – wheel tracking and bending beam test - experience, that the weaker the asphalt stiffness of the more rigid the net effect prevails, that is, the greater synergistic effect does extra stress in addition.

<u>5. thesis</u>

I could justify that after hampered strain test there are no differences between the grid strengthened and non grid asphalt structure at the cold cracking temperature. The hampered strain test is not capable for analyzing the grid strengthening, because the length of the grid is not changing therefore is not able to take over stress from the deformed asphalt. Contrarily after at the -10 C° made tensile test we can say that the built in grid between the two asphalt layers improve for more than 11-19% the tensile strength value of the structure. [4] [18]

At asphalt testing the cold side of bearing is such is so important than the warm attitude of the asphalt. Above all the grids are advertised for the brand-switcher as materials which are adapted to the cold thermal stress. In the next image colored with green the results of AB-11/F mixture and with blue the results of the mAB-12/F mixture. I analyzed 60 specimens for the tests.

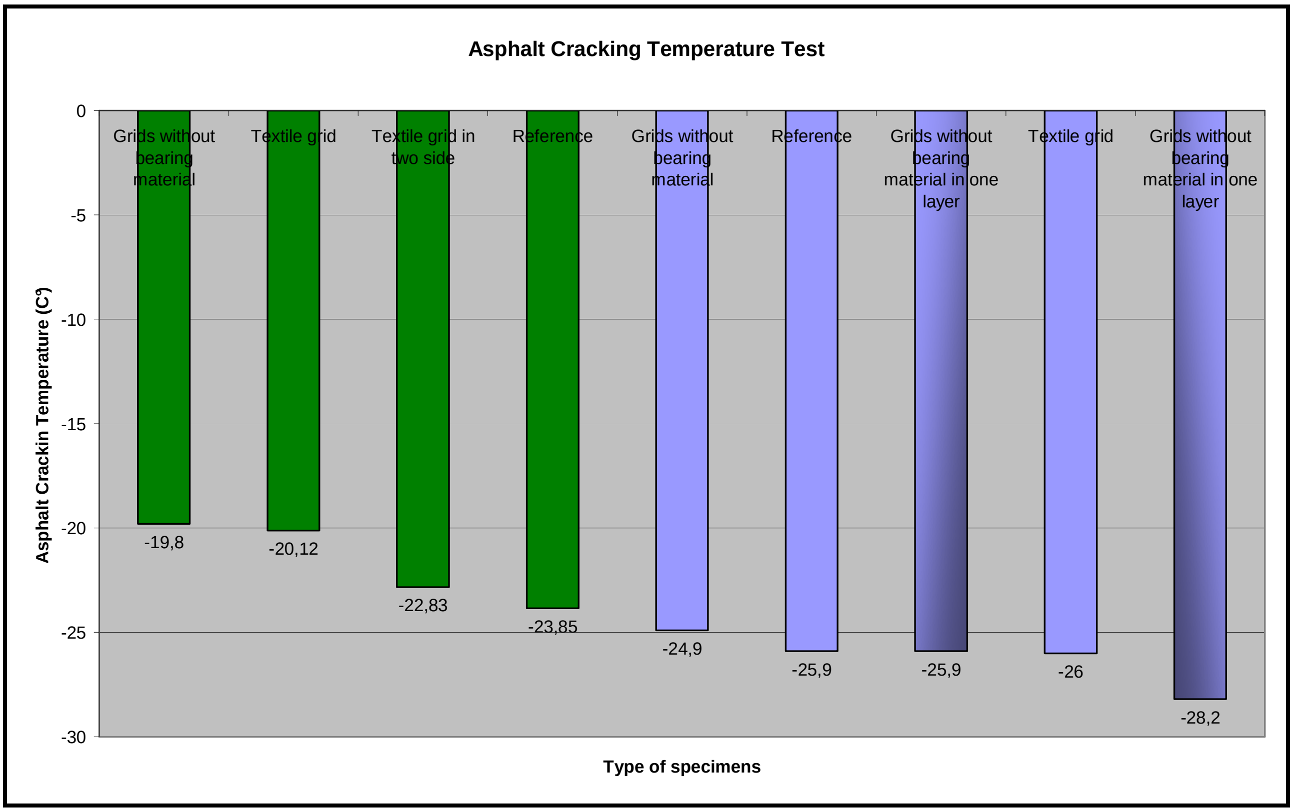

Image 7: Results of the Asphalt Cracking Temperature test

Above, Image 7. clearly shows that the temperature of crack the asphalt wouldn't appear significance in determining differences between samples prepared with and without implants. The operating principle of deflection inhibited during the investigation because the grid can not stretch follow the contraction of the asphalt occurs and can not play a role in temperature caused by deformation of the structure.
At temperature -10 ˚C the pure cracking test, compared with an assessment of the ARH, the measurement uncertainty over the value of the difference improves the tensile of the asphalt without the substrate.

The next image shows the results of the clear tensile test at -10C°.

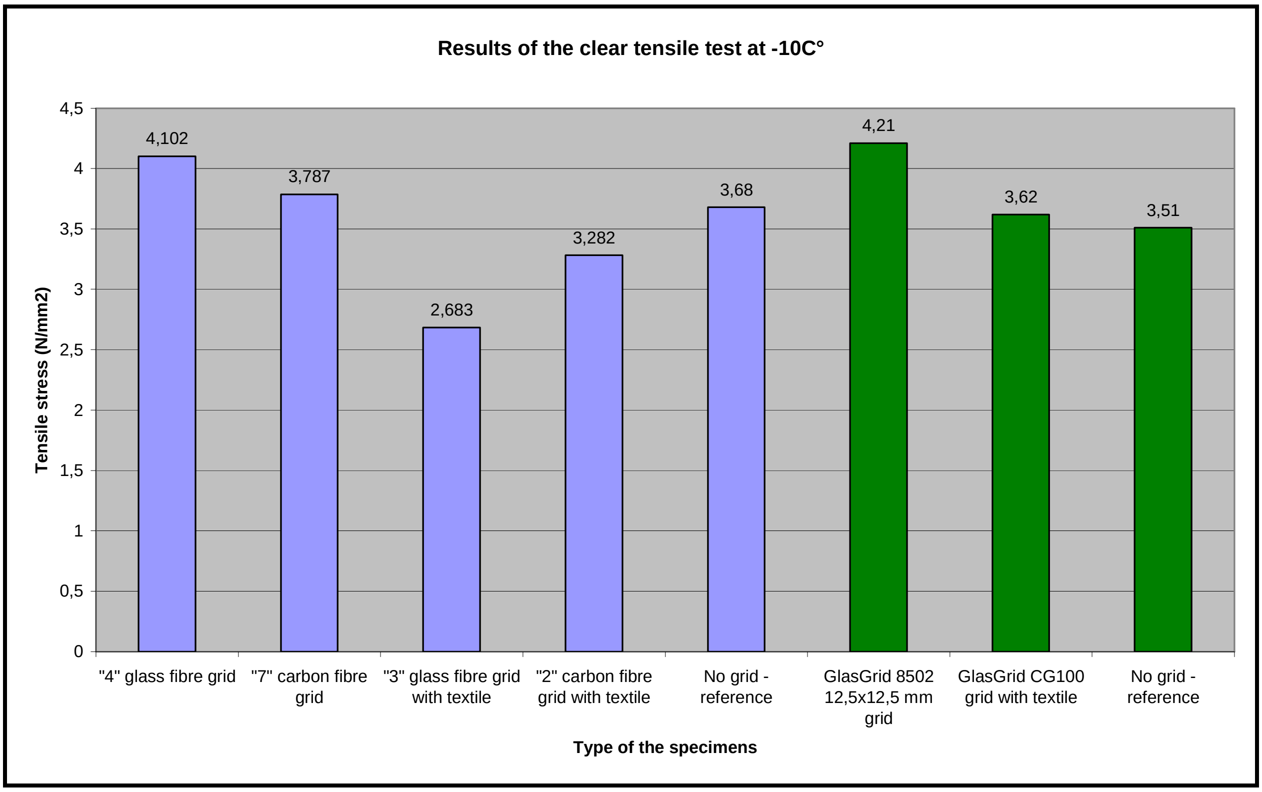

Image 8: Results of the clear tensile test at -10C°

6.1. thesis

I justified with BISAR testing, that the asphalt grid only starts to work when the stiffness of the above asphalt layer increase because of carrying capacity defect and cracks. In this case it has been justified that the grid is suitable for crack prevention, on the other hand at the less stiff asphalt structure the grid has been starting to work at the beginning. Therefore is effective to apply grid with higher stiffness module and smaller strain behavior. [4] [18]

In the next image we could see how important the stiffness of the grids because the 100.000 MPa module grids give the smallest displacement results and even at a full slippery situation the grids still have been working.

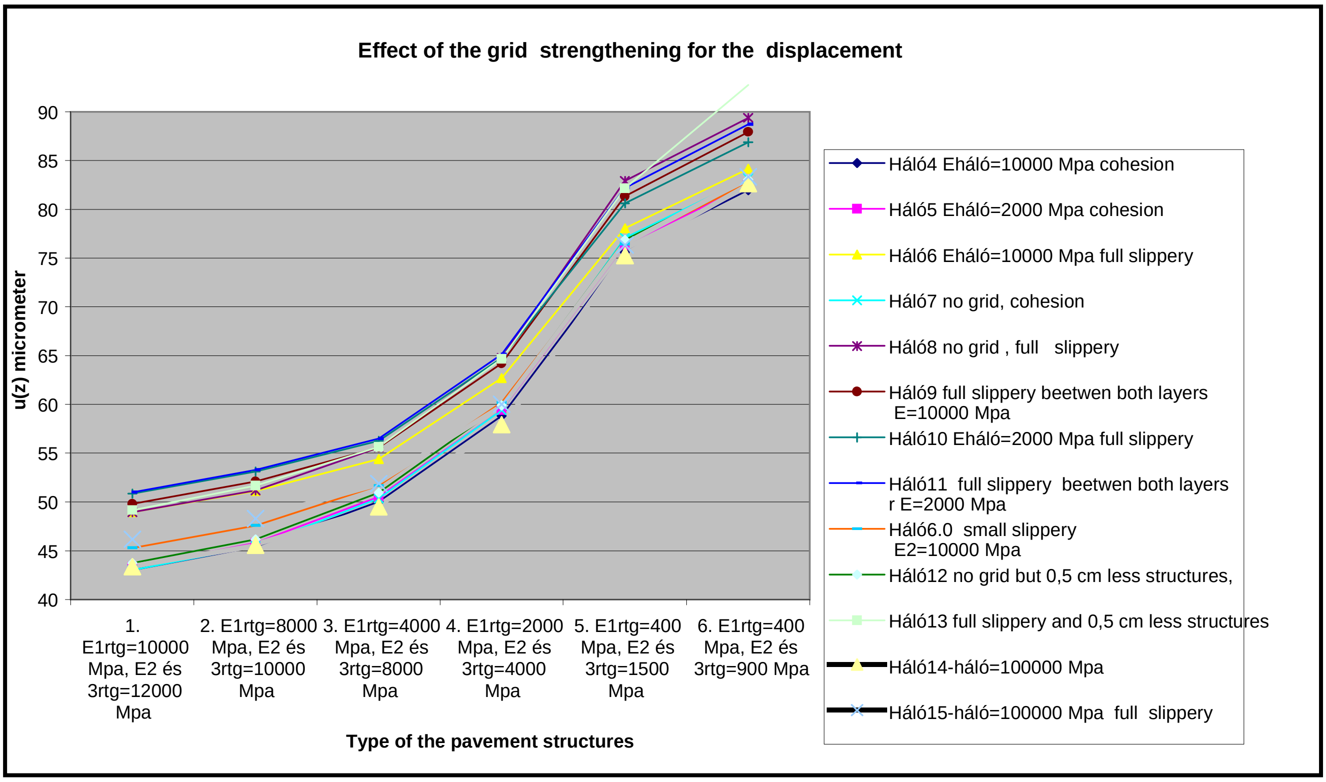

Image 9: Effect of the grid strengthening for the displacement

6.2. thesis

I verified that below the binder course, at the case of 13 cm deep grid reinforced structure would be the smallest the measured strain at the bottom of the 2. and 3. layer contrary of grid situated 4, 5, 6 cm deepness. Depending of the structure condition and failure the strain would be 26-43% less if we build in the grid below the binding course. [4] [18]

At the **Image 10** clearly shows up that significant difference arise between the models around failure of the structure, and in this case under the binder layer at 13, cm deep the strain would be 26-43% less.

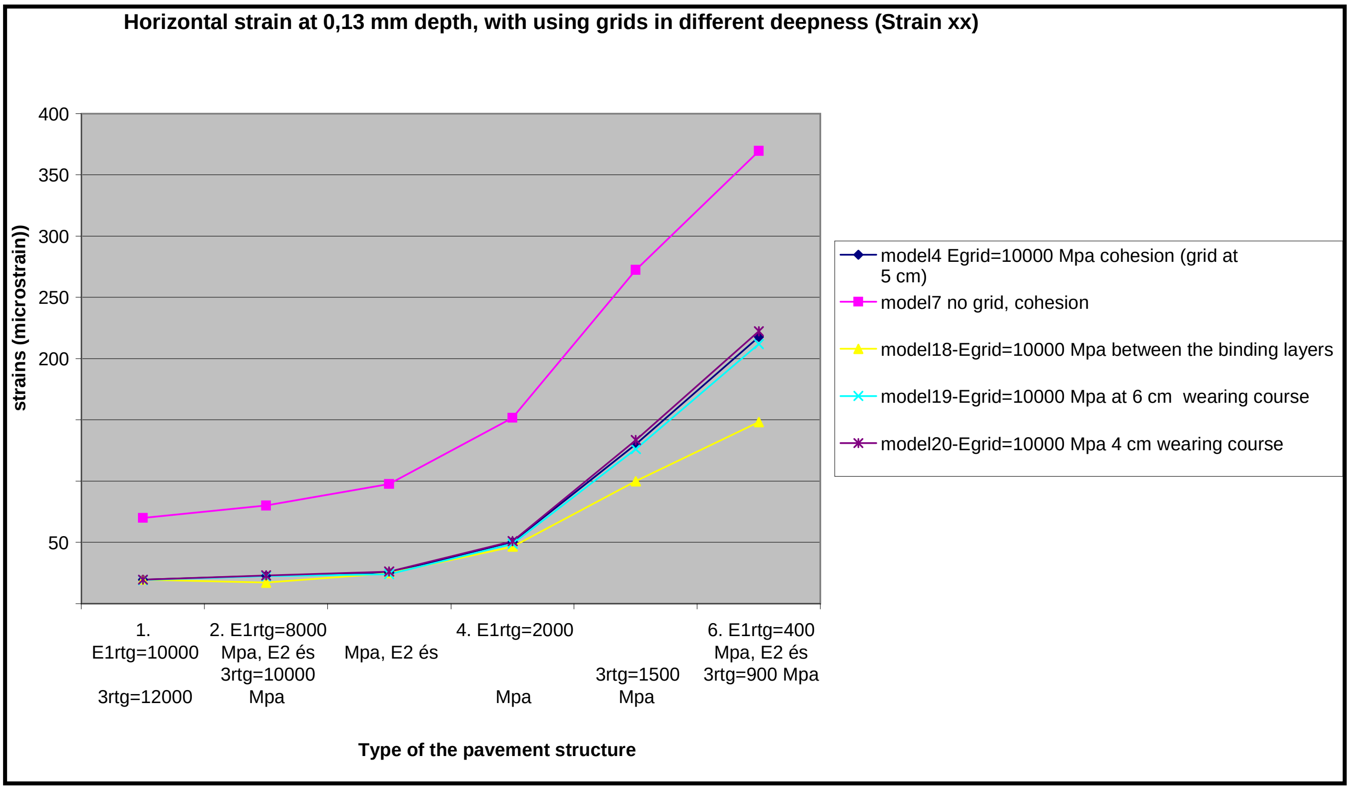

Image 10: Horizontal strain at 0,13 mm depth with using grids in different deepness

7. thesis

With the finite element modeling I proved that grids can be considered as replacer if there stiffness is bigger than 10.000 MPa. The modeling showed that fortifying effects came in above 30-50 C°, which shows that net should reach a better heat resistance for asphalt pavement. [3] [4] [17]

Using finite element model it was determined that the application grids, regardless of how many borders are grid used in the structure, it constitutes a substitute thickness. The replacement thickness advantageously increase the size of the net for weaker structures are used. Really serious (centimeter scale amplification), equivalent thickness can be achieved if the installation has a large grid stiffness modulus (10.000 to 20.000 MPa). Second, the grid under the binder course further increases the thickness of equivalency, using the third layer will not lead to the more strengthening of the structure.

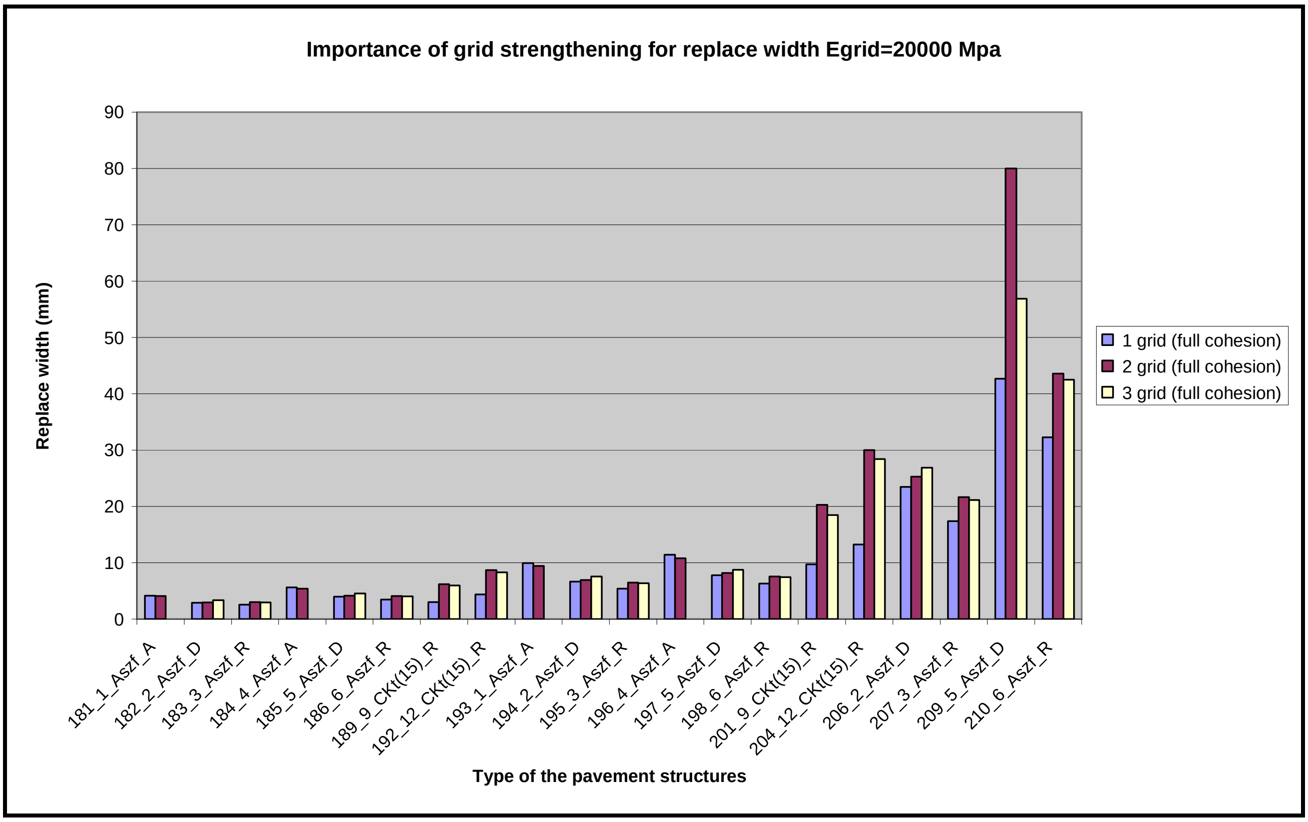

Image 11: Replace width applying 20.000 MPa module grids

Running the final elements it is clear that applying the 2nd grid gives a new reinforcement to the structure since in these cases almost 100 percent of the time the replacement width has increased except when using the class „A" asphalt pavement structures. Applying the 3rd grid though – compairing to the 2-grid-structures - does not always mean that the structure will get stronger. In those cases when the 3rd grid is placed under the wearing course I can only achieve a very slight increase in the replacement width. When we were using the CKt baselayer or the 4-layer asphalt pavement though the replacement width has slightly decreased after applying the 3rd grid.

3. Summary

In my studies of the reinforcing asphalt grids my goal was to find out how much help these components can be when using them building into the asphalt pavement structure. During my research I studied how much strengthening effect the asphalt grid had on the appearance and fatigue resistance of the wheal track. Using the computer model of the final elements and the Shell-BISAR I also absorbed how much the application of the grids can increase the life expectancy and how much it can support the replacement width. During these examinations I also paid lots of attention to the existence of how much these layers can strengthen each other since it has a huge effect on whether the reinforcement components are effective or not.

In summary we can conclude that the asphalt grids can improve the asphalt pavements' physical attributes but they can only make serious positive impact on the weaker structures or on the ones which are close to be ruined.

We can also say that the asphalt grids' success depends very much on how the components are built in and the layers can strengthen each other. During the research I also found answers to the optimal places of the grids within the pavement.

Basically three types of grid types were applied in this thesis. No carrier grid, texture based grid, and in some cases iron grid were used. The studies clearly showed that the asphalt using wireless carrier is recommended due to better cooperation between grids, while the impact strength and fatigue characteristics rutting trials texture-based grids is also shown for the reinforcement was significantly positive effect.

In these examinations it also turned out how important the stiffness of the grids, because the grids with enough stiff and small strain can get reliable strengthening.

4. More researching suggestions

After the wide research I would like to declare that we need to make an appropriate official road standard which will be included the justified meanings, technical parameters and building possibilities. (I suggested separately deal with the module of the grids)

I presented visual inspection results about some grid strengthened roads in Budapest and a country side, but furthermore I suggested a wider visual inspection – about the cracking situation and displacement measurement – such road where built the pavement with grids and we know similar part of that road without any grid strengthening.

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