



## THE AGGLOMERATIONS AND ROADS – LESSON TO BE LEARNED

Mensur Mulabdić<sup>1</sup>, Nikifor Petrović<sup>2</sup>

<sup>1</sup>Consultant, LETA d.o.o., Croatia

<sup>2</sup>Consultant, Niki Consulting d.o.o., Croatia

### Abstract

This paper presents a case study on one section of the regional road from the program of agglomeration analysing design solution, selection of the materials used for backfilling, backfilling method, and compaction of placed materials. It is compared to international standards and recommendations. Unexpected settlement and sinking occurred after completion of the work, and they were assessed to be due to the presence of water which was not detected during site investigation and possible internal erosion within the backfilled materials. The special laboratory testing was prescribed and conducted with the aim to measure sensitivity of prescribed material to erosion. In addition to the above, some trial work on the site was carried out by controlling thickness of the placed layers and compaction methods which proved to provide good results. In conclusion, the authors emphasise importance of the adequate site investigation, design details, technical specification and compaction technology to achieve suitable outcome.

*Keywords: agglomeration, roads, design, backfill, compaction, control*

### 1 Introduction

Agglomeration activities which take place within the existing infrastructure (roads) require proper knowledge of soil and water conditions of the site, appropriate design, construction according to the standards to achieve technical requirements with particular attention to pipe installation and backfilling of the trenches with suitable materials and compaction method. When failing in some of these activities postpone settlement of the new pavement may occur and whole work must be done again, which is connected with extra cost and time that normally are not counted for during tender preparation. One such case was studied after substantial damage of pavement was detected on finished sections of the road with aim to detect reasons for it and to establish procedures for work execution to avoid any remediation afterward. Therefore, the design solution, water conditions, backfill materials and compaction criteria were studied as follows:

- a) design solution was compared to rules accepted worldwide for trenches,
- b) laboratory testing of backfilled material in terms of its sensitivity to erosion under the water flow within trench, and
- c) controlled compaction in the field by measurement of dry density and modulus of compacted soil by dynamic plate.



- The ideal material for trench backfill under the road is crushed limestone, which contains both fine grinding and grain particles up to 12-25 mm in diameter. Properly graded (well graded) crushed material has a good grain composition and ensures grain composition which allows to achieve high compaction, strength and resistance to subsidence (crushed gravel can also be used, but with not so good impacts compared to crushed limestone)
- Smaller fractions of crushed materials or gravel (max particles 9-18 mm) can be used but this material can absorb a lots of water due to fine content. Sieved material can cause an arching in the upper zone of thick layers during compaction, which can lead to the wrong conclusion about the good compactness of the backfill, while subsequent subsidence in uncompacted (deeper) zones may occur. That's why many engineers avoid gravels, sands and/or selected sieved material.
- The sensitive compaction zone is around and above the pipe and it usually requires manual compaction. Well-graded crushed gravel or crushed limestone for that zone is recommended.

So, there are three key factors controlling the behaviour within the trench: selection of the quality materials (particle size distribution and mineralogical composition), compaction in layers 15-20 cm, achieve compaction degree to meet 95-98% density by Proctor procedure (standard or modified, better the latter).

It is very common that the Investors do not allocate enough money for site investigation what leads to less boreholes at greater distances (200-300 m), and important information about soil (like soft layers) and presence of water (local appearance) cannot be adequately detected and included in design solution. Very often, the time for site and laboratory testing is underestimated and is not included in the design and construction programme.

## 2 Laboratory investigation

During execution of the work, water ingress into the trench at the section that suffered subsidence was registered and it required dewatering using the pumps. Sources of water were damaged local infrastructure (water pipes), local water wells, local aquifers and seepage from the surface. Due to the slight inclination of the installation trench, water flow was noticed around the installed pipes with possibility to wash out the fine particles from the placed materials.

It was potentially considered to be one of the causes for settlement of the backfilled material and consequently of final structure – pavement. Special testing program was designed to evaluate potential of washing out of the fines from backfield material.

The filtration test carried out is shown on the Figure 2. The tested sample was placed within the tube with the elbow supporting a vertical pipe to maintain different gradients. Different hydraulic gradient applied and water flowing through the sample together with fine particles was collected at the end of the tube. The tests were running as long as necessary to ensure that clear water was coming out from the tube. For each test setup see Table 1.



Figure 2 Filtration test setup used for materials 0-4 mm and 0-32 mm

Grain size analysis of the materials before and after testing were carried out as well as of small particles washed out from the original material. The results are shown on the Figure 3. and Figure 4. for the two tested materials. The dry mass percentages of the washed out portion of the genuine fill are presented in Table 1.

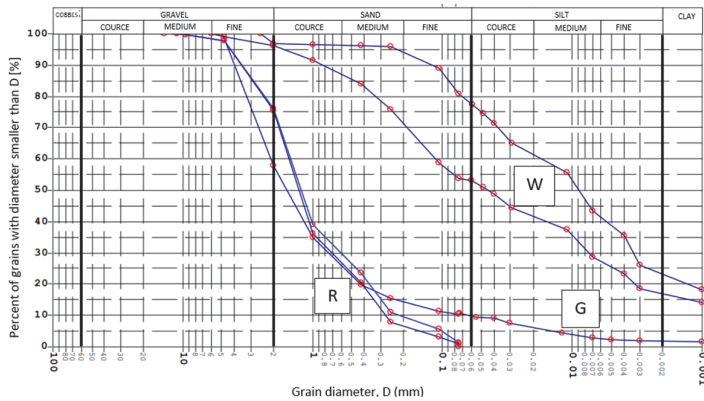


Figure 3 Grain size distribution of the genuine fill material (G), retained material (R) and washed out material (W) for the fill 0-4 mm

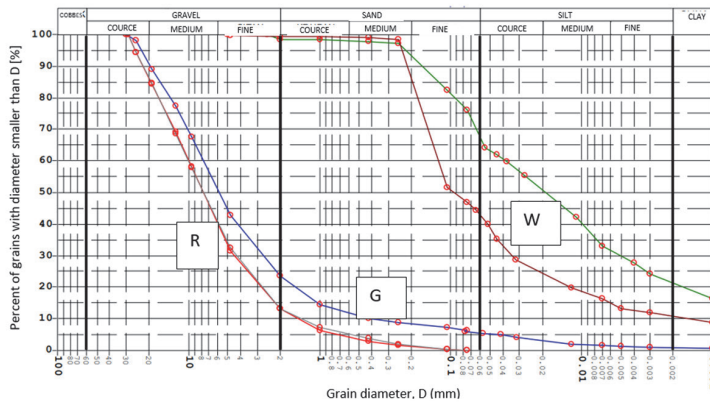


Figure 4 Grain size distribution of the genuine fill material (G), retained material (R) and washed out material (W) for the fill 0-32 mm

Table 1 Percentages of washed out materials for different hydraulic gradients

Gradation [mm]	Hydraulic gradient	% mass washed out
0-4	0,48	0,89
	2,6	1,25
0-32	0,68	2
	1,3	9,82

It can be seen that significant amount of small particles can be washed out under certain conditions of water flow within the trench. When five percent of particles by mass is washed out, the porosity of material will increase by 3% causing an additional settlement of about 6 cm for a 2 m thickness of backfill material.

### 3 Field control testing

The major factors controlling settlement are compaction methods of the fill material and achieved density after compaction. In addition to it, a method of placement and spreading of the fill material within the trench is of significant importance as well to prevent segregation of the particles. Therefore, a trial section inside the trench was performed with the aim to evaluate appropriate placement and compaction with respect to the achieved density compare to the Proctor values and dynamic plate modulus.

Two trial – test sections were performed, one with smaller compaction energy (4 passes by 500 kilos plate compactor and 4 passes by small sheep roller), and second one with double number of passes by same equipment as used along the first section. These two types of compaction equipment were available on the site and therefore they were chosen for compaction. Both sections were about 10 m long, and on each section measurements of density (water balloon method) and modulus by dynamic plate were carried out at three measurement points at about 3 m distance.

Those measurements were performed after compaction by plate compactor and again after compaction by small sheep roller. The compacted layer was about 20-25 cm thick. The obtained field test results (dry densities and modulus) are presented on Figure 5. It can be seen that densities of 95% modified Proctor or higher are achieved together with high modulus  $E_{vd}$  providing adequate compaction effort was applied. It is clear that high values of dry density (min 95% of modified Proctor) and dynamic modulus can be achieved if thickness of layer is adopted to ensure that the required compaction will be achieved with respect to compaction energy applied. Placement of material was done in controlled manner by loaders to avoid free falls from the trucks. Placement of the materials by unloading directly from trucks is a typical mistake in the practice where segregation occurs within placed materials in the trench. Pockets of segregated materials are weak spots facilitating migration of the particles and additional settlements.

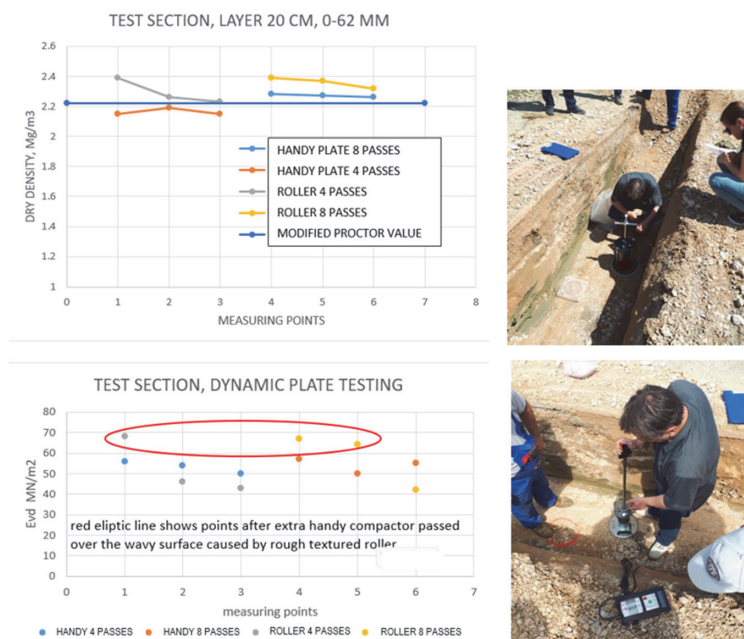


Figure 5 Results of density and stiffness control on test section

## 4 Conclusion

This paper presents a case study analysing and discussing challenges and problems related to the agglomeration works along the existing roads. It assessed the reasons for the pavement subsidence after the work has completed. The assessments were related to the design solution with respect to the selection of backfill, execution of work, soil and ground water site conditions. To better understand and emphasise sources of post-construction problems, the international recommended principles regarding this type of activities were presented to compare to usual design solution. In addition, the special laboratory and in situ investigation testing programs were performed. Based on the findings of this study, the following conclusions can be drawn out:

- Post-construction settlement can be avoided if design solution is adopted with respect to the real site conditions, if proper materials for backfill are selected and used (grain size distribution, layer thickness) and if compaction energy is adequate
- Quality control of compacted backfill should include control of dry density and stiffness determined by dynamic plate test (Proctor modified values of min 95% is recommended to be used as a reference for good compaction)
- The international recommendations for design and execution are available and should be respected and applied
- Field trial tests are recommended prior to the commencement of the work to define method specification with respect to thickness of layer, compaction equipment and number of passes QA and QC needs to be implemented and supervised during work execution

## References

- [1] Babcanec, J.: Proper installation of corrugated HDPE pipe, Practical tips on how to provide the best underground burial, Concrete Construction, 2012.
- [2] Construction specification for trenching, backfilling, and compacting, Ontario provincial standard specification, 2021.
- [3] ASTM D2321-74: Recommended Practice for Underground Installation of Flexible Thermoplastic Sewer Pipe, 2017.
- [4] ASTM D2321-20: Standard Practice for Underground Installation of Thermoplastic Pipe for Sewers and Other Gravity-Flow Applications, 2020.