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ASSESSMENT OF EARLY DAMAGE IN NEWLY CONSTRUCTED LOW VOLUME LOCAL ROADS

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Abstract

Recently, there have been observed pavement distresses in newly constructed low volume local roads in the northern area of the West Bank. This has impacted functionality of the roads, and resulted in waste of resources. The paper analyzes three case studies, proposes solutions, and identifies the lessons learned for avoiding such problems in the future. Related problems were visually observed, especially the presence and propagation of longitudinal and edge cracks of varying extent and widths. The existence of such pavement distresses demanded investigating the reasons behind such early unexpected distresses. Based on that, it is required to search for practical, technical and economical solutions for the already defected sections. This paper therefore investigates the reasons behind the appearance of such defects during short periods of time after construction through visual inspection, in addition to review relevant soil reports, in order to check the nature and classification of the soil as well as the presence of shallow water table in the area. Finally, based to the results of the assessment of the case studies, the researchers provide proper solutions to avoid such problems in the future. The paper ends with proper recommendations and highlighted lessons learned.

Keywords: Early pavement distress; pavement cracks; low volume roads; local roads.

1. Introduction

In this section, the case study is presented and the problem statement is defined. Three roads are the target of this case study assessment, which are located in Jaba' and Sanour, Jenin Governorate. The first case study describes the generated pavement distresses after few months of finalizing asphalt works in specified roads in Jaba' town. The second case illustrates the pavement defects in newly constructed local road in Sanour village, while the third case study, Al-Khirbeh local road, is also located in Sanour.

Before introducing each of the roads included in the case study, the contents of the paper are illustrated first. In the next section, literature review describing a number of studies in similar settings is presented. Next, the methodology followed is illustrated. This is followed by analysis of each of the case studies, which is considered as the basis for the consequent section on proposed treatments. Finally, the paper ends with conclusions and recommendations.

1.1. Jaba' Internal Roads

The first case study includes five internal roads in Jaba' town which have the following numbers; R1, R4, R5, R6, and R7, respectively. These roads had longitudinal and edge cracks parallel to the road centerline and to the shoulders. Moreover, longitudinal cracks were noticed along the joint between the asphalt layer and the adjacent concrete shoulder, in addition to similar cracks in the body of road shoulder. The degree of severity varied from low to severe and the width of the cracks ranges from 0.5 to 4.0 cm. These cracks were deep and reached the subgrade. The same cracks in terms of width and depth were noticed also in the shoulders and adjacent natural lands. This fact emphasized that the subgrade soil is weak and needs to be improved, strengthened and stabilized.

The sub-surface drainage was also one of the main problems in the targeted roads. The local people declared that some springs are located beneath the roads which caused cracks as the soil suffered from expansion (swelling) after being fully saturation with water. The bad drainage of water on both sides of the roads with the absence of culverts was contributed in appearing the different types of cracks as illustrated in Road No. 7. It is worth to mention here that the number of vehicles passing through these roads is very few as most of the roads are dead end roads and providing the accessibility to the internal quarters of the town, thus considered as low volume roads. Accordingly, the effect of the traffic loads can be neglected. Figures 1 to 3 illustrate the existing defects and degree of severity in the targeted roads and adjacent lands.

Figure 1. Centralized longitudinal cracks with medium severity, Jaba'

Figure 2. Centralized longitudinal cracks with low severity, Jaba'

Figure 3. Cracks with different degree of severity in the adjacent lands, Jaba'

1.2. Sanour Al-Khirba Internal Road

The second case study includes Al-Khirba internal road in Sanour village. The length of the road is about 400 m. The road was under construction in the excavation works and importing rock fill materials for some sections while conducting the first site visits. The existing soil is very poor and classified as A-7-6 which is silty clay soil with red color (UG, 2019). This implies that the soil should be replaced up to certain depth with the help of the supporting layers. The soil is expansive as it swells in the winter and shrinks in summer. Figure 4 depicts a general view for the existing problems in the road, while Figure 5 illustrates the poor nature of the soil (UG, 2019).

1.3. Sanour Al-Rabba'at Internal Road

The third case study includes Al-Rabba'at internal road in Sanour village. The length of the road is about 350 m. The road was paved less than one year ago. The existing soil is very poor and classified as A-7-6 which is silty clay soil with red color (UG, 2019). Longitudinal cracks were noticed in the road and with medium to high severity. The soil of the subgrade is noticed to be expansive and the water table is shallow. Figure 6 illustrates the existing pavement defects in the road. The lack for proper drainage in specific sections along the road (lack of drainage facilities such as pipe culvert), as well as the lack in proper compaction for shoulders (the base course material of the shoulders was crumbled and segregated), contributed in increasing and accelerating the failure of the road as illustrated in Figure 6.

Figure 4. General view for existing problems in Al-Khirba internal road, Sanour

Figure 5. Poor nature of the existing soil, Al-Khirba internal road, Sanour

Figure 6. General view for existing defects including lack of drainage facilities and proper shoulder compaction in Al-Rabba'at road, Sanour

2. Literature Review

In this section, several studies related to the causes of pavement failure and at specific for low volume roads are presented. The main reson behind that were the exisitng of expansive soil and the water table is some how close to the subgarde. These studies are illustrated hereafter.

Hauser et al. (2018) illustrated that the low volume roads in the Czech Republic are roads with lower traffic volume that primarily include forest and field roads, and they are an integral part of the Czech transport network. When building road pavements, the processes used for surveying, designing, building and inspecting road constructions included in European standards. In addition, the roads were evaluated in terms of their environmental impacts, in order to maintain the quality of the environment. However, during the construction of road pavement, decisions based on financial, time and other reasons were made. The decisions had impacts on the operation of roads and lead to other measures and additional costs of repairs and reconstructions. The article summarized the authors' research results from constructions of low volume road pavements and contains evaluations of laboratory and in situ material tests (soils, layers) of installed road pavements as well as evaluations of modelled laboratory and long-term monitored in situ structures.

Zumrawi (2015) presented some issues of geotechnical investigation for roads built on expansive soils. The aim of the study was to provide road engineers with guidance on site investigation; field and laboratory identification of expansive soils. A clear understanding of the expansive subgrade soils behavior and their geotechnical characteristics has been of more interest to the study in order to assess properly the source of the swelling problem. Two case study sites, representative known problem-areas in Khartoum, Sudan, were carefully selected for geotechnical site investigation. The field exploration consisted of excavating trial pits and collecting soil samples from the subgrade. These soils were subjected to laboratory testing for measuring the particle size analysis, consistency, strength and swelling characteristics. The soils were found to have over 50% clay particles, high plasticity index more than 30% and high free swell index of 160% to 250%. The compacted samples were found to have swell potential of 7% to 15% coupled with high swelling pressure in excess of 90 kPa and low strength, CBR values less than 4%. General conclusions had been drawn from the study findings.

Dessouky et al. (2014) explained that the expansive soil is one of the most common causes of pavement distress. Expansive soils undergo changes in volume due to moisture fluctuations from seasonal variations. These changes are reflected in the stability and performance of pavement layers. The objective of this research was to evaluate existing repair projects on selected farm-to-market roadways. Those roadways experienced failures in the form of fatigue and rutting along the wheel path, and longitudinal (faulted) cracking, including edge cracking. Those failures were due to high-plasticity expansive soil and narrow pavement lanes. This research study implemented visual survey, field and laboratory testing, ground penetrating radar scanning, and structural design evaluations for three project sites to evaluate existing pavement treatment options. Using up to 14 years of performance records, this study suggested that geogrid reinforcement combined with lime-treatment is an effective repair at areas with low to moderate plasticity soil. Also, cement-treated base was found to be an effective treatment option in areas with high-plasticity expansive soil.

Vandana et al. (2013) studied ten rural roads in three different districts namely Indore, Dhar and Jhabua in India. The length of each study section was fixed as 0.5 km. Each study stretch was further divided into 10 sections of 50 m each. Detailed surveys had been carried out on all the ten road sections. Road Inventory Survey included properties of bitumen and soil, rainfall, temperature, properties of shoulders, sub base, base and type of adjoining land etc. The main results were:

1. The traffic observed on selected roads is very low and therefore had minimal influence on the performance of rural roads. Hence the causes for the distress of these rural can be identified as drainage and construction quality.
2. The main distresses identified in the rural roads are Rutting, Edge drop, Cracking and Roughness.
3. Ravelling was found to be absent on the selected sections. A few numbers of potholes were observed on some places of the road sections due to poor drainage and construction quality.

Dafalla and Shamrani (2011) performed surveying considering major road damages attributed to expansive soils with particular focus on Saudi Arabia. Roads and light structures in various parts of this country experienced damage as a result of moisture increase and environment changes to subgrade soils. Strains in asphalt pavement due to volume change in soils can lead to cracking and attract water seepage to lower formations. An attempt was made to link the road damage to the soil conditions, road geometry and road drainage arrangements. The parameters influencing the swelling process including thickness of pavement, slope of the shoulder, adjacent topography and drainage setup are discussed. Recommendations to achieve better road performance are presented through the applications of cut-off walls and dressing layers were suggested for certain conditions.

Caunce (2010) investigated the current Ipswich, England, and world best practice pavement design and rehabilitation techniques. Ipswich geology was determined and soil data collected and analyzed to determine the extent of expansive soils and the degree of correlation between the Atterberg Limits. A collection of existing pavements were surveyed and correlations drawn with regard to the pavement and subgrade materials and condition. As a result, alterations to the Ipswich Planning Scheme Policy for pavement design have been suggested. The findings showed that the most effective method of subgrade treatment currently appears to be geosynthetics placed on the subgrade. Results showed also that, on expansive soils, a flexible surface should be constructed on an impermeable membrane or layer since flexible bases experience fatigue which can be easily maintained whereas rigid bases can crack rapidly and to the detriment of the entire foundation. Identification of the cause of pavement failure is necessary to determine the appropriate rehabilitation method for a failed pavement. The study recommmended to consider sustainable rehabilitation methods that maintain a flexible pavement with asphalt surfacing.

Zornberg and Gupta (2009) used basal reinforcement of pavement systems for the purposes of: (i) increasing the lifespan of a pavement while maintaining the thickness of the base course, and (ii) decreasing the thickness of the base course while maintaining the lifespan of the pavement. Moreover, a third application of basal reinforcement of pavements, namely, the mitigation of longitudinal cracks induced in pavements constructed over highly plastic, expansive clay subgrades. This includes information showing that: (i) geogrid reinforcement has precluded the development of longitudinal cracks in pavement sections located in projects where unreinforced sections have shown significant cracking, (ii) longitudinal cracks are 'shifted' beyond the reinforced pavement zone, avoiding their development within the pavement itself, and (iii) that current specifications, which often rely on geogrid properties defined in isolation, are insufficient to fully characterize the reinforcement requirements for reinforced pavement project. Overall, the field observations highlight the significant benefits associated with the use of geogrids in pavements over expansive clay subgrades, although there is still the need for more rationale design methodologies.

Muench et al. (2007) considered a case study in the City and County of Honolulu, USA, on implementing a long-lasting low-volume pavement strategy captured dissatisfaction with disposable pavements and one particular implementation plan. While ultimate success can only be measured over time, their adherence to some, but not all, the discussed best practices shows that it is possible to implement a long-lasting low-volume pavement strategy, and acceptance of such a strategy by the professional community can be near unanimous.

Hall et al. (2003) stated that most highway-safety related research in the United States over the past 40 years had focused on major facilities (freeways, arterials, interchanges or intersections), or on specific treatments (traffic control devices, roadside barriers, rumble strips). Little effort had been devoted to a systematic assessment of potential safety improvements on low-volume rural roads, such as those administered by most counties, some states, and certain federal agencies. Although treatments that were safety effective on higher traffic volume facilities should also improve safety on low-volume roads, they may not be cost-effective. The authors analyzesd the crash occurrence and potential safety treatments on low-volume rural roads. A safety survey was developed and distributed to a sample of those officials responsible for these roads. Using traffic volume data and traffic accidents for 1998-2001, potential field study sites were identified on rural state highways in New Mexico with average traffic volumes of less than 400 vehicles per day. Computer analyses of the accident data identified some common patterns among crashes on these roads. Field studies, somewhat less rigorous than road safety audits, were undertaken on nearly 300 miles of these highways for the purpose identifying potential low-cost countermeasures that could be effectively deployed at spot locations. The findings and recommendations from this research may be of interest to those responsible for enhancing safety on low-volume rural roads.

3. Methodology

The following flowchart illustrates the steps followed in the paper to evaluate the current structural pavement situation in the targeted roads. The process starts by office work through reviewing the exiting design, lab tests, and evaluation reports. The second step is conducting site visits to the targeted roads and collecting the necessary field data through visual inspection. The third step is to analyze the collected data by studying the causes of such defects in the asphalt layer and evaluate the effectiveness of the applied treatments. The final step is to identify the main conclusions and to propose recommendations and perspectives for future improvements. Figure 7 illustrates the followed methodology.

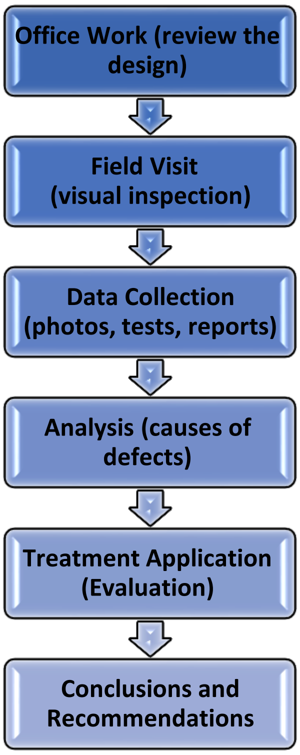

Figure 7. Research methodology

4. Analysis of Case Studies

4.1. Jaba' Internal Roads

The visual inspection and captured photos through conducting the site visits illustrated the existing problems in the targeted roads which can be summarized as follows:

- Longitudinal cracks were located along the centerline of the road due to the poor subgrade and the absent of drainage facilities such as culverts.
- Edge cracks were also noticed due to the poor subgrade, high level of underground water because of springs, the inadequate pavement thickness, and the unstable condition of subgrade and soil beneath (noting that the existing soil is expansive).
- Longitudinal cracks in the joint area between the protected concrete shoulder and the asphalt layer due to non-homogenous materials, the lack in compaction for the shoulder as seen from the disaggregate base course material, in addition to the week subgrade.
- The level of the surrounding natural land is the same as the roads and accordingly this would enhance the negative effect of water on the edge part of the road.
- The conducted soil tests indicated that the results before and after asphalt works were not matched. The classification of the soil was A-2-6 and A-2-7. However, the classification of the soil after extraction of asphalt tile was A-7-6 which was not consistent with the municipality tests.
- The structure of the road was composed from two layers; 20 cm base course and 6 cm wearing asphalt. However, in some certain and specified sections such as R7, an additional rock fill layer was added. This design was proposed to overcome the problem related to the high level of water table in the area.

4.2. Al-Khirba Internal Road in Sanour

The analysis of the results of the visual inspection and captured photos through conducting the site visit to the targeted road illustrates the following:

- It is clear from the previously shown photos that there is week soil needs to be replaced to a certain depth with the presence of other supporting layers.
- The need for pipe culverts in the low point as the surface of the road is almost level.
- The level of the surrounding houses is taken into consideration in the design to ensure the safe access.
- The reviewed soil tests' reports for the road indicated that the road is located in an area of week soil type which had bad results in terms of its capacity for expansion and shrinkage (expansive soil). The soil

swells in the winter and shrinks in the summer, which negatively affects the pavement structure and the layers above.

- The review process for the design plans (existing at local village council) emphasized the need for redesign of the road. The new proposed cross section of the new structural design is illustrated in Figure 8. Moreover, the need for improving the longitudinal and cross slopes is urgent to ensure reaching surface water to the lowest point.
- The new proposed design included replacing the existing soil with a depth of 1 meter instead of 90 cm with an emphasis on 70 cm of rock fill layer to improve and strengthen the base of the road. The proposed design includes also the addition of 30 cm thickness boncor layer, then a 20 cm layer of base course, and finally an asphalt wearing layer with a thickness of 6 cm. This design is compatible with the functional classification of the road (local).
- To ensure that water is well discharged and not collected below the road base, a geotextile layer is proposed below the boncor layer. This will contribute in minimizing the effect of rising water table.
- The designer stressed the need for frequent compaction for all included layers of the road, including the rock layer to ensure reaching the needed percentage (100%).
- The need for cleaning and removing the fine particles covering the existing rock fill layer.

4.3. Al-Rabba'at Internal Road in Sanour

The analysis of the results of the visual inspection and captured photos through conducting the site visit to the targeted road illustrates the following:

- The road is located in the same quarter of Al-Khirba road and consequently it has the same soil characteristics.
- The nature of the soil is clay soil with red color.
- The high severity of the existing longitudinal and edge cracks is due to the week subgrade, poor drainage especially for the adjacent and surrounding lands.
- The poor compaction for shoulders led to the dropping and as a result appearing of the cracks.
- The existing design of road is composed from 30 cm thickness rock fill layer, 20 cm base course, and 5 cm asphalt. This design is expected to reduce the impact of high level of water table in the road. However, due to the similarity with Al-Khirba road, the previous proposed structural design is compatible.
- The need for installation of additional pipe culver is urgent to ensure full discharge of collected water (ponds).
- The levels of the adjacent houses should be taken into consideration for future improvements.
- The deep patching and reconstruction are urgent actions to repair the current defects.

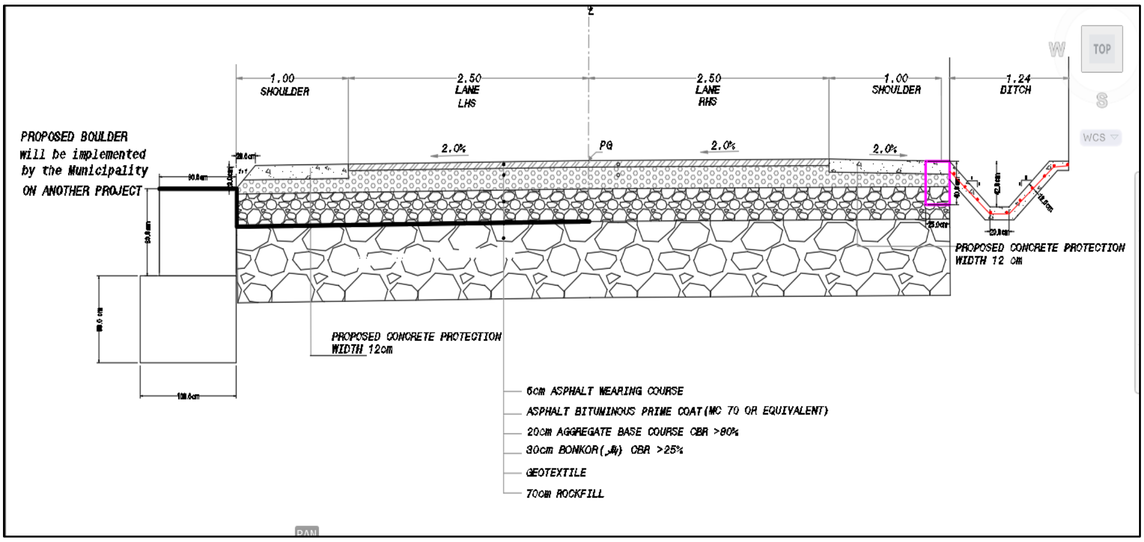

Figure 8. The new proposed structural pavement design

5. Treatment Application

5.1. Jaba' Internal Roads

The type of the applied treatment was based on the severity levels. For example, the low severity cracks were treated using the seal coat. The contractor filled the cracks after ensuring reaching to the maximum width of the cracks by the end of summer season. The drainage problem in R7 was solved by installation of 40 cm pipe culvert. This will contribute in minimizing the seepage of the surrounding water ponds through the structure of the road. The medium to high levels of severity cracks were treated by applying concrete injection in to the faults. The depth of the cracks crossed beneath the structure of the road up to the subgrade. The applied concrete through the bore holes would increase the stability of the subgrade and the remaining road layers. The application of such treatment was under the supervision of the municipality engineer. Figure 9 illustrates the proposed treatment.

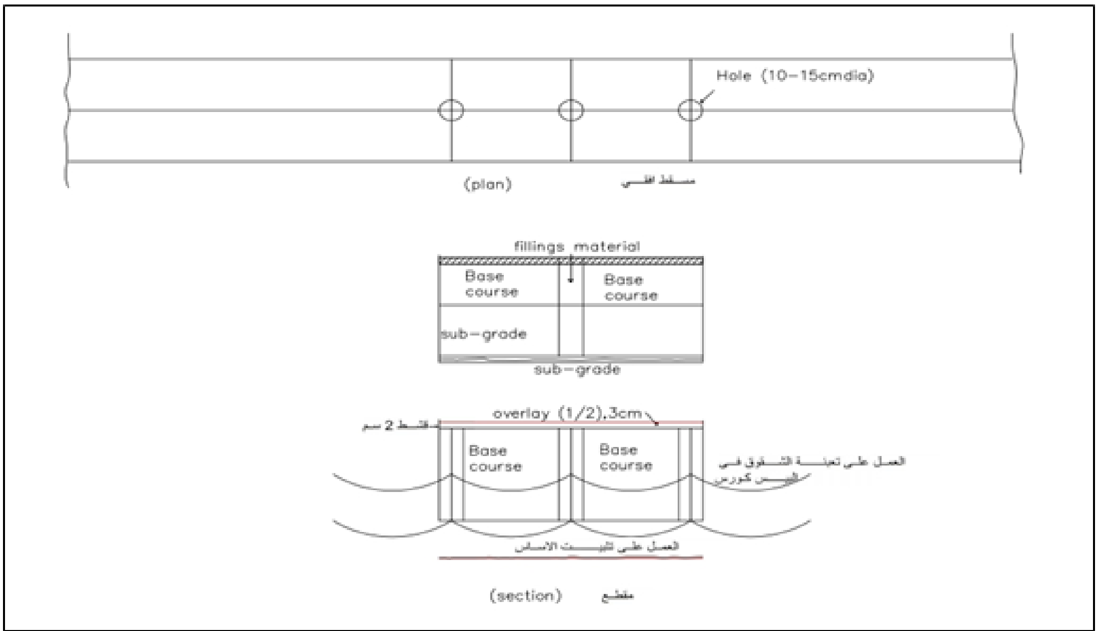

Figure 9. The applied treatment in the targeted roads

5.2. Sanour Al-Khirba Internal Road

The current situation of the road is good in general as the road was recently paved as illustrated in Figure 10. However, some defects were noticed recently in certain locations in the road as presented in Figure 11. Moreover, the local village council is preparing for the concrete protection for shoulders, which will also protect the asphalt layer. The challenge of the lack of drainage at the low point in the level area in the road is overcome by construction of a pipe culvert of 60 cm diameter taking into consideration the inlet and outlet points as well as the level of entrance for the adjacent houses as presented in Figure 10. The need for cleaning the outlet area is mandatory to ensure smooth discharge of water.

5.3. Sanour Al-Rabba'at Internal Road

The road is partially treated at specific sections using cold asphalt especially for low to medium severity sections. The applied treatment is not enough and does not cover all defects in the road. The applied treatment is shallow and does not reach to the base of the road. Figure 12 illustrates the application of the cold asphalt. The pavement deterioration in the road is increasing dramatically as shown in Figure 13, which demanded urgent economic and effective actions.

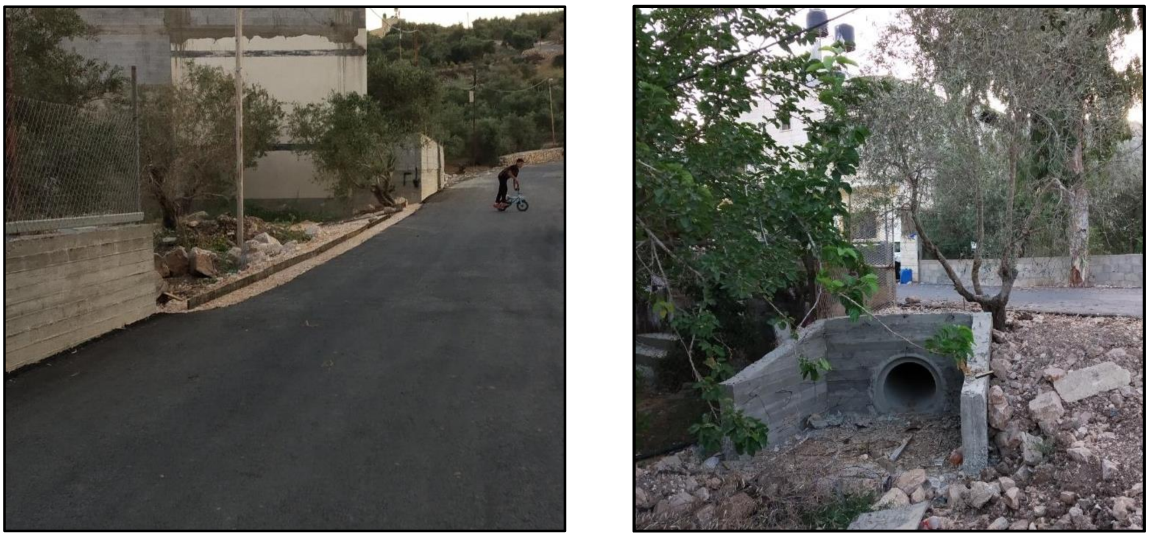

Figure 10. General overview of the road and the constructed pipe culvert across the road

Figure 11. Recently noticed defects in Al-Khirba road

Figure 12. The treated sections in Al-Rabba'at road

Figure 13. The dramatic increasing pavement distresses in Al-Rabba'at road

6. Conclusions and Recommendations

6.1. Conclusions

Based on the conducted site visits and reviewed evaluation reports and lab tests, the following can be concluded:

- The construction of the roads was based on design prepared by the municipality or local village council. However, the proposed design was not compatible with the existing conditions on the ground.
- The existing pavement distresses and defects need to be treated properly. The implemented actions were not enough and other more practical and effective methods could be applied.
- The applied treatments and actions should be comprehensive and complete, as the partial treatment of such defects will have limited overall effect, and, therefore, can extend the life of the pavement for only a limited time.
- The treated cracks in Jaba' internal roads are still generally in good conditions. However, due the poor quality of subgrade (expansive soil) and the higher level of the water table, new edge and longitudinal cracks appeared with different severity levels in certain and specific locations.
- The conducted site visit to Al-Khirba internal road in Sanour which was recently paved illustrated that the problem of drainage in road was solved by construction pipe culvert across the road. Moreover, the structure of the road was implemented based on the proposed design by the local consultant. The structure of the road is composed from 1.0 m rock fill layer in addition to 30 cm boncor layer, 20 cm base course and 6 cm wearing asphalt layer. Finally, the shoulder and asphalt layer were protected by applying reinforced concrete.
- Regarding the third case study in Al-Rabba'at internal road in Sanour, the local village council treated some longitudinal and edge cracks in certain low to medium level of severity. These cracks were treated using cold asphalt filling materials. However, the remaining sections were not treated and the existing faults' depth reached the subgrade. Moreover, the width of the existing cracks ranges from 2 to 10 cm. Finally, the overall rating of the road is poor to very poor.

6.2. Recommendations

The authors recommend the following for the considered case studies:

- The local governmental units are highly recommended to assign a Consultant to prepare the proper design and drawings. Moreover, the task of supervision should be the responsibility of the designer.
- It is recommended to apply comprehensive and complete treatments. While partial treatment actions to remedy such defects may extend the life of the pavement for a limited time, the comprehensive remedial measures will for sure preserve the pavement structure for a long time.
- For internal roads in Jaba', it is recommended to treat the existing defects as soon as possible using the similar procedure applied previously and respecting the type of defect's severity. For future rehabilitated internal roads in Jaba', a proper design is recommended which should take into consideration the poor and weak nature of the subgrade soil (expansive) and the high level of water table and the existing of springs.
- Despite that the overall general pavement conditions are acceptable in Al-Khirba internal road, and where the road was recently paved, it is recommended to wait for the end of maintenance guarantee period to check the quality of implemented works.
- The existing pavement conditions is Al-Raba'at road is very poor. The authors recommend to treat the existing edge and longitudinal cracks as soon as possible. As the nature of the subgrade soil is similar to that in neighboring Jaba' town, it is recommended to use the same treatment procedure.
- It is recommended to use geotextile layer in case of the presence of high water table in order to minimize the effect of the nearby high level of the water table on the asphalt layer.

In broader terms, it is recommended to pay attention to the design of local low volume roads similar to the attention given to higher volume highway. It is recommended that proper studies and investigation of all the existing local conditions, including soil condition and sub-surface water flow conditions, to be considered in the design stage. Local standards for design of the low volume roads should be prepared. Finally, once a problem is observed on such roads, proper monitoring and evaluation is to be thoroughly done to come with proper solutions, without allowing the problems to propagate and reach a point where total reconstruction is needed, especially for newly constructed roads.

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