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The Improvement of Asphalt Pavements in Urban Areas with Cold In-Place Recycling and Its efficient Management Using (GIS)

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ABSTRACT

Today, the most important criteria in urban infrastructure in cities is efficient and favorable asphalt roads and this increases the importance of optimizing these roads. One of the most advanced and scientific methods in this subject is cold in-place recycling which in addition to high performance, has many distinguishing features compared to other methods, including: economic justification, environmental compliance, ergonomic design, recycling of materials, reduction in traffic, faster operating speeds compared to common methods and complying with the technical issues approved by Iran's road pavement regulations. One of the other subjects in this study is using the geographic information system (GIS) in the reconstruction of asphalt coatings which due to its great capabilities in providing reference location data, can be used to better manage the asphalt recycling method. The main question in this article that we have tried to answer is "how can we use the geographic information system to implement an optimal and economic cold in-place recycling?"

KEYWORDS: Urban pavement, Rehabilitation of asphalt, Recycled asphalt, Cold in-place recycling, Geographic information system (GIS).

1.INTRODUCTION

Today, after the road networks in a country have been completed, the next priority should be the maintenance of those roads[1].

With that being said, the necessity of using a new method which is both economical and also technically and environmentally approved is obvious. In this regard the use of recycling technologies in the production of asphalt is an acceptable and optimal solution. It is the reuse of old asphalt material that is damaged and reduced in technical capability or is declining, Asphalt recycling has many advantages and is known as one of the fastest and most efficient methods for rehabilitation and reconstruction of asphalt coatings[2].

Repairing, maintenance and the improvement of roads has high costs therefore these costs must be spent in the optimal time, otherwise the maintenance and repairing operations would be uneconomical. The key component in an integrated program is to manage maintenance, control the service status and performance of pavements and the amount of damage. Therefore, in order for the management and maintenance to be done at an acceptable level, a management support system is necessary. In figure 1, the importance of recycling can clearly be seen, especially economically.

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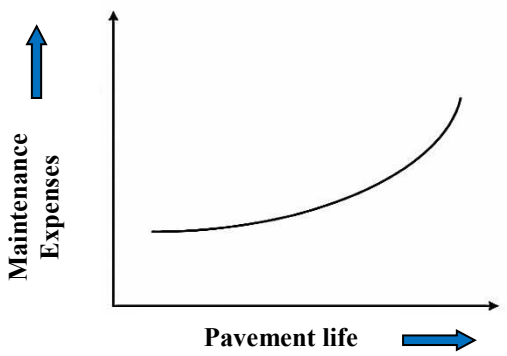

Figure.1. Costs of maintenance and pavement life

Today, there are various systems that could be used for this purpose, but in this study due to the size of urban road networks and the high maintenance costs, we have chosen to use the geographic information system (GIS) as the pavement management system.
The introduction to everything said above is the pavement condition index (PCI). Using recycling to improve the overall and periodic maintenance of road pavements has a clear and significant cost saving. Figure 2 is an overview of this matter[3].

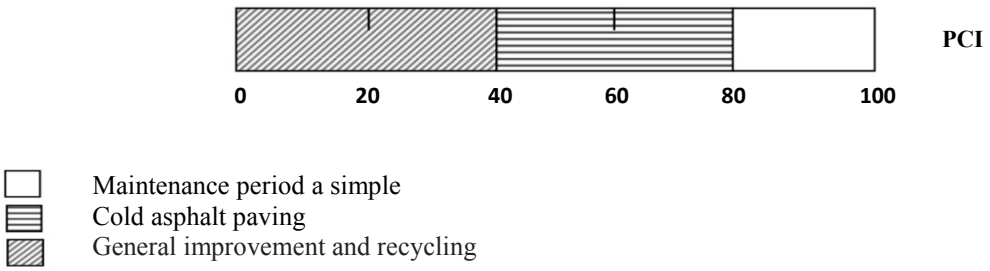

Figure. 2. Guide to using PCI to determine the type of reform needed

2.Cold-Mix Recycling

In the cold in-place recycling method that is more common than the cold plant recycling, all the reclaiming is done in-place using special machinery. This method reclaims part or all of the asphalt layers and cuts and crushes it. Then the crushed material is graded and bitumen is added. Using this method we can build up to 30cm in depth. In many of the states of America the cold in-place recycling method has took place alongside hot asphalt paving[4].

Although cold recycling does not have a long history, it has a high speed and performance quality but is less common compared to hot recycling. With this method worn-out and injured asphalt in the surface or underlayers can be strengthened with the restoration of its aggregates and bitumen materials. Although the implementation of this method saves in energy consumption, reduces overall costs and improves conservation of natural resources due to its high operating speeds, it is suggested to use this method only when the volume of recycled materials for the project is high[5].
Cold asphalt recycling has its own characteristics which have been mentioned below[1,5]:

- Optimizing the base and sub-base layers and repairing the sub-grade layer
- Short time gaps between mixing and compacting the layers
- Increasing the quality of pavements without increasing the volume
- Removing the reflective cracks and the thermal cracks of the pavement
- Increased pavement resistance to moisture and icing

2.1.Mix Design
The specifications and design of cold recycling mixes are in the ASTM standards[6]. Two methods are used for the recycle mix design:
1.Mix with bitumen emulsion
2.Mix with bitumen foam
Each method has been described separately below:

2.1.1.Cold Recycling Mix Design With Bitumen Emulsion
For this mix design the modified marshal method is used according to(ASTM-D1559) or (AASHTO-T245) standards[2]. The appropriate bitumen emulsion for cold in-place recycling is selected according to the essential characteristics listed below:

- Gradation
- Whether the bitumen is anionic or cationic
- Whether the bitumen emulsion is medium-setting (MS) or slow-setting (SS)

In cold in-place mixes the choosing of anionic (ASTM-D977) or cationic (ASTM-D2397) bitumen emulsion is done depending on the type of stone materials as well as their compatibility with the bitumen. Therefore medium-setting (MS) emulsions are used for large gradation and slow-setting (SS) emulsions for small gradation[7].
The final results for cold recycling mix design with bitumen emulsion include:

- Determination of the type of bitumen emulsion used in the project
- Determination of the optimum bitumen content
- Determination of the optimal mix of water
- Determination of the recycle gradation
- Determination of the amount of stone material and RAP used
- Determination of the amount of additives used

2.1.2.Cold Recycling Mix Design With Bitumen Foam
There is no standard or single method for determining the cold recycling mix design with bitumen foam. Therefore a criteria has to be used based on parameters such as durability and long-term behavior. The method that the cold recycling regulations manual of Iran has mentioned for designing the recycled mixes with bitumen foam, consists of parts mentioned below:
1) Determination of the characteristics of the project
2) Choosing the appropriate stone material
3) Determination of the type of asphalt mix
4) Determination of the bitumen type
5) Determination of the moisture percentage
6) Preparation of laboratory samples
7) Check compliance of samples with the criteria of design
8) Structural design of mix

2.2.Production and Implementation of Cold In-Place Recycling
Cold recycling of asphalt consists of cutting, plowing, scraping and crushing the asphalt layer, with or without the base and subbase layers. The materials will be spread and compacted again after they have been reprocessed either on site or a central cold recycling plant.
In this method the recycling materials are mixed with bitumen such as bitumen emulsion or bitumen foam and additives such as cement, flyash and new stone materials if necessary. The result will be a new recycled asphalt with good structural performance.

In general, the implementation of cold in-place recycling includes the following steps:

- Scraping the asphalt pavement
- Crushing the reclaimed materials
- Adding new stone material to the mix according to the mix design
- Gradation of the new mix

- Mixture of the material with bitumen and additives according to mix design
- Spreading the recycled mix on the road surface
- Compacted the recycled mix

In this method some executives must be respected as below:

- The slope of the road
- The thickness of the recycled layer
- The optimal speed of machinery
- The ambient temperature and its limitations on the implementation of recycling

2.3.Control Tests

In cold asphalt recycling quality control, the results of each test must match the technical criteria, including: the gradation of recycled mix, bitumen material and additives, the amount of water added to the recycled mix, the remaining water of the compacted mix, the strength quality of the bitumen foam mix, compaction of the layers, determination of the voids in the mix, calibration of the equipment and etc. [8].

The most important control tests that are used for cold recycling samples are as listed below[9]:

- Unconfined compression test (UCT)
- Indirect tensile strength (ITS)
- Tensile strength ratio (TSR)

3.Justification of Cold In-Place Recycling

The most important parameters of recycling is its feasibility and its justification which include: significant reduction in production costs, economic savings in projects, observance of environmental principles and the reduction of resource consumption including bitumen and aggregate.

Among the most significant and environmental characteristics of asphalt recycling are[8]:

- Accomplishment of reconstruction and development goals
- The preservation of natural resources due to the reuse of pavement materials
- Reduction in the costs of operation and maintenance of the routes
- Reduction of environmental pollution
- Reduction in the costs of production and transportation of raw materials and energy savings (bitumen, diesel, electricity,etc)
- Increase in speed and efficiency of operations
- Decline in traffic due to open operating routes during the recycling

4.Recycling Urban Pavements

The schemetic diagram below is a comparison between the methods and practices conducted by the usual and recycling methods, interms of speed as well as the economic point of view[10]:

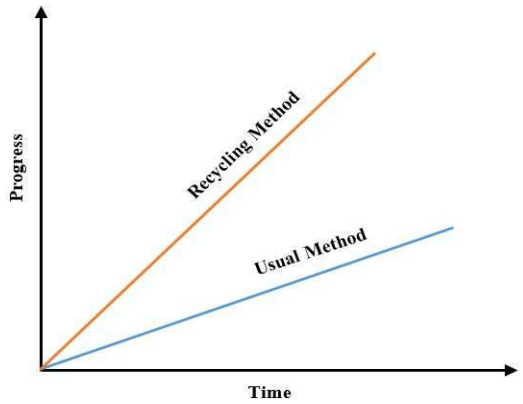

Figure. 3. Comparison of operating speed

5.Paving Management Using GIS

5.1.Features and Amenities of GIS

GIS consists of hardware, software, organizations and processes designed to enter data into different mapping systems, data storage, data transfer, management, manipulation, analysis and the production of different outputs including maps, reports and project plans. According to this definition GIS is used as a processor for combining spatial and attribute data.

GIS has the ability to attach descriptive information to a data location (which is a coordinate on the ground) and can compose a logical relationship between the collected data. Although some of these features exist in other systems and software but GIS has provided all of these capabilities in one user-friendly and easy to use comprehensive platform. Some of GIS's capabilities and features are mentioned below[11]:

- The schematic presentation of maps in a graphical environment
- Having a flexible editing environment for database
- The ability to apply different formulas in order to facilitate new relationships in data
- Statistics functions such as maximum, minimum, standard deviation etc.
- Depiction of charts
- Ability to use matrix
- The ability to create networks for roads

In general, geographic information system (GIS) can be used to gather and analyze data used to map the damage, in terms of type of damage and severity of damaged pavements condition and also map the parts that need maintenance, improvement or modernization.

5.1.1.Road network

After the road network has been determined, it is then divided in to smaller parts for better management. Each network is divided in to smaller parts called branches and each branch is divided into smaller parts called segments. By having the branch and segment lengths we can calculate the paving area in each condition. These calculated areas are a great information source in order to schedule, estimate budget needed, prioritize projects and estimate the volume of materials for the project[12].

5.1.2.Determination of Pavement Condition Index (PCI)

The pavement condition index is currently the best method for pavement analysis. This index is recognized by ASTM standards. The grading is done in the range of (0 to 100) and for asphalt pavements, the road pavements are assessed according to the level of damage. The damages are evaluated on three levels: low, medium and high.

The PCI can be determined based on experience and on a visual inspection of the pavement where three parameters of the type of failure, failure quantity and severity of the damage are accounted for Mohseni and Pirhadi[13].

For this purpose you must first determine the extent of the area which it is to be studied and after preparing the networked map, convert it to a shape file format that can be used in the ArcGIS software. Then the road network is detected and then the network is divided to branches and the branches to pavement segments. The network branches and segments must be labeled and coded. After recording the damages in the provided forms (according to the PCI guide) the severity of the damages are divided in to three categories: low, medium and high severity.

After the data collection and evaluation of the pavement conditions, information of each section is defined to the identification code for that piece and is placed in a specific folder for that segment. The information system files and registers each segment according to the time and date of receiving that information, in order to collect a failure history file.

Different areas can easily be set in the program for PCI with different colors in order to achieve a visual of the general situation. For example, the following coloring can be considered in the figure bellow[14]:

1) Green: Good condition ⇒ **(100>PCI>70)**
2) Yellow: Medium condition ⇒ **(70>PCI>55)**
3) Red: Poor condition ⇒ **(PCI<55)**

Figure. 4. Determination of the pavement condition index

5.2.Planning for Maintenance of Routes With The Help of GIS

In order to make decisions for the maintaining and repairing of roads, it is necessary to collect information with respect to the previous paragraphs, then give the necessary information to the administrators and planners to estimate and present a policy.

The outputs of the GIS software are: mapping of the pavement conditions and the type and severity of damages, showing the PCI, networking of sample units and longitudinal cracks according to the severity of damage. With a view based on the GIS's outputs, we can start prioritizing in different ways, such as budget, main roads, pavement life, traffic and etc. and make the final decisions with regard to the organizations policies[13].

6.Conclusion

As discussed in this paper the recycling of pavements has many positive parameters compared to the usual methods, which have been pointed out in this paper (economic, environmental, technical, etc). The important factor is to achieve the ideal conditions and optimization of the recycled mix, which can be achieved according to the environmental characteristics of the project.

Another article in this paper that we have tried to review is the optimal management of the asphalt pavements in urban areas using cold in-place recycling and the creation and operation of an urban management system with the goal of using the capabilities of the geographic information system (GIS) which could ultimately lead to the optimization of pavement maintenance and cut costs, in a way that a manager could manage the routes and other facilities of vehicle transportation using the geographic information system (GIS).

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