Resources, Conservation and Recycling 83 (2014) 112–120

Contents lists available at ScienceDirect

Resources, Conservation and Recycling

journal homepage: www.elsevier.com/locate/resconrec

Field investigation of pavement rehabilitation utilizing cold in-place recycling

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ARTICLE INFO

Article history:
Received 21 April 2013
Received in revised form
14 December 2013
Accepted 16 December 2013

Keywords:
Pavement rehabilitation
Cold recycling
Bitumen emulsion
Cement
Performance monitoring
Destructive and nondestructive tests

ABSTRACT

Despite the widespread field and laboratory research works there are still a lot of unknown aspects about the cold in-place recycling. This paper presents the outcomes of a five year evaluation of a major highway in Iran which had been rehabilitated by cold in-place recycling. Before starting the rehabilitation process, a comprehensive field survey was performed. During the pavement surveying, type, severity and reason of distresses were investigated and PCI parameter was calculated. Furthermore, both destructive and nondestructive tests were carried out to evaluate the pavement condition and estimate the remaining life. On the basis of these investigations studied highway was divided to six design sections. Based on technical analysis four sections were recycled whereas two other sections were rehabilitated with the conventional cold milling and overlay method. Afterwards, the pavement performance was monitored during the next 5 years. After about six months of monitoring, structural failures were detected in about 10% of recycled areas. Based on field surveying, low compaction and load bearing of subgrade materials and lack of high quality unbound pavement layers accompanied by some shortcomings in recycled layer resulted in undesirable results in these areas. Based on obtained results and performed analysis a practical flowchart was presented which could be used as a project selection guideline.

1. Introduction

Due to technical, economical and environmental advantages, use of cold in-place recycling (CIR) has grown especially in most industrial countries. Reduction of using natural aggregate quarries, lower energy consumption, several environmental benefits and the feasibility of full depth renovation of pavement structure are some obvious advantages of this technique. Apart from the above-mentioned advantages recent enhancements in the CIR machinery capabilities and the quality of emulsion production are some other important factors which will reduce the construction time and increase the total efficiency of rehabilitation process. Normally, similar to other innovative rehabilitation methods, CIR has also some inherent shortcomings. Project selection is one of the main challenges which engineers are encountered with. Variability of pavement conditions such as the changes in type and thickness of layers, type and amount of bitumen and existence of patching areas along with the severe variations in subgrade soil quality are some important issues that will increase the difficulty of project selection. Furthermore, designer must have a good insight about the type and capabilities of CIR equipments that will be used in the rehabilitation process.

Recycling or reuse of existing pavement materials for pavement rehabilitation, reconstruction and maintenance is not a new concept. Literature indicates that pavement recycling existed as early as 1915 (Area 2001). However, the use of modern CIR equipments dates back to 1990s (Area 2001, Iowa highway research board 2007). Notwithstanding the vast amounts of field and experimental research studies, there is not a comprehensive instruction or internationally accepted standard which could cover the requirements and details of materials and methods related to this rehabilitation technique. In 2007, Iowa highway research board published the results of a comprehensive laboratory and field study about the long term performance of recycled roadways in various regions of United States. According to this report, choosing a recycling method which truly matches with existent equipments and project conditions will considerably increase the chance of project success. The results of this study showed that if it is properly selected the direct economical advantages of recycling will be more than the 60% of other feasible rehabilitation methods (Iowa highway research board 2007). In addition to direct economical advantages such as reducing the need for origin aggregate materials and energy consumption, CIR needs lower construction time than conventional

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0921-3449/$ – see front matter
http://dx.doi.org/10.1016/j.resconrec.2013.12.011

methods. Furthermore, it could be performed in a single lane with lower traffic disruption than other methods which need full width obstruction.

Previous experiments confirmed that the recycled layer with lower stiffness and higher air void behaves like a stress absorbent layer (Iowa highway research board 2007; Miro et al., 2004; Suleiman, 2002). It should be noted that even with sufficient load bearing capacity the recycled layer should not be used in the upper surface layer. At least, it is always needed to construct a thin surface course on top of the recycled layer. Low abrasion resistance against the impact force of heavy vehicle tires, especially on the initial curing days and relatively high air void content are the main reasons which indicated in literature (Miro et al., 2004; Suleiman, 2002; Moreira and Simoes, 2004). High permeability of recycled layer will detrimentally affect the durability and long term performance of pavement. Besides, the final surface of recycled layer is not as smooth as the conventional hot mix asphalt. Therefore, in order to increase the riding quality it is necessary to place a hot mix asphalt overlay on the final surface of recycled layer (Suleiman, 2002; Moreira and Simoes, 2004). Higher air void content in recycled layer (usually 10–20%) is attributed to existence of water in mixture which will absorb a part of compaction stresses and reduce the compactibility of layer. Moreover, in mixes which stabilized with cement or other pozzolanic additives the higher initial stiffness will reduce the compactibility and result in higher air void contents. The latter case could also increase the roughness of recycled surface (Salomon and Newcomb, 2000; Rita et al., 2001; Issa et al., 2001; Miller et al., 2006; Oruc et al., 2006).

Climatic condition is a key parameter for selecting the type of recycling, equipment and additives. The minimum ambient temperature for recycling with bitumen emulsion and foam bitumen is restricted to 10 °C. At lower temperatures the deficiencies which related to cold recycling with foam bitumen is the lack of adequate cover or bitumen film on the surface of coarse aggregates. In the case of bitumen emulsion prolonged curing period is the main reason which indicated in literature (Miro et al., 2004; Julian and Zhanping, 2010; Hamad et al., 2012). In the wet conditions the use of bitumen emulsion will be more successful than foam bitumen. Basically in these situations construction of hot mix or even warm mix layers may result in unfavorable results (Julian and Zhanping, 2010; Hamad et al., 2012).

Based on the previous experiments, the major investigations that engineer should perform during the project selection period are shortly consist of evaluating the existent pavement condition by monitoring the type, frequency and severity of surface distresses, sampling from the asphalt, base, subbase and subgrade layers for controlling the layers thickness and performing the laboratory tests on the extracted materials. The history of construction and previous maintenance activities and detailed traffic data are other important information which should be gathered by consulting engineer (Salomon and Newcomb, 2000; Iowa highway research board 2007).

Although the most pavement distresses can be rehabilitated by CIR, but cracked pavements with structurally sound, well-drained bases and subgrades are the best candidates (AASHTO AGC-ARTBA joint committee, 1998; Thomas et al., 2000; Berthelot and Gerbrandt, 2002). Thus, old oxidized asphalt pavements with fatigue cracks, reflection cracks, rutting due to unstable mix, shoving and raveling can be successfully repaired by CIR method (Kandhal and Malick, 1997; Batista, 2004). However, not all pavements are good candidates for CIR. Among the pavement distresses those that are less successful if corrected with CIR are as following (Epps, 1990; Forsberg et al., 2001; Fiser and Varaus, 2004):

- Rutted pavements caused by too high asphalt content.
- Failure caused by wet, unstable base, subbase or subgrade.
- Failure caused by heaving or swelling occurring in underlying soils.
- Pavements that exhibit stripping of the asphalt from the aggregate.

In addition several other conditions warrant special consideration when using CIR that some of them includes the following (Epps, 1990; Forsberg et al., 2001; Fiser and Varaus, 2004):

- Long steep grades or those exceeding 5% and 2500 ft in length will reduce production and may require extended traffic control.
- Heavily shaded areas where little or no sunlight reaches the pavement will require longer curing times.
- The minimum asphalt pavement thickness to be cold recycled should be 2 in.
- The presence of several manholes or drainage inlets within the pavement area.
- Addition of new gravel to the recycled aggregate pavement (RAP) to obtain the minimum treatment depth should not exceed 25% by weight of the RAP. Otherwise, a significant increase in emulsion content, thus higher cost will occur.

Some other considerations in deciding whether a project is a good candidate for CIR include the project size, pavement and shoulder width and traffic volumes and congestion. Projects of 40,000 m^2 or more are the most economical but some smaller size jobs may be feasible (Fiser and Varaus, 2004; Kai et al., 2009).

2. Research objectives

Most recent studies have focused on the laboratory properties of CIR mixes that usually examined the mix design process. This paper presents the results of a 6 year study about the performance of CIR layer which has been constructed during the rehabilitation process in Semnan–Damghan highway. The overall work plan consisted of the initial field investigations before selecting the rehabilitation method, construction process and performance monitoring during a 5 year period after the construction completion.

The main objective of this research was to determine quantitative criteria on the basis of both laboratory and field data. In this regard, considering the results of destructive and nondestructive tests the minimum engineering properties will be presented for various underlying layers of pavement structure (i.e. CIR, base, subbase) and subgrade layers.

3. Project overall specification

Semnan–Damghan road is a major divided four lane highway in Iran with the total length of 105 km. The first 60 km of Semnan–Damghan direction (i.e. south passway) and the total length of the opposite direction (i.e. north passway) with the approximate length of 105 km were studied in this research.

4. Field investigations

The initial field study was started in March 2005. The historical data of initial construction and periodic maintenance were gathered from the archive of technical and soil mechanic laboratory and the road office of Semnan province. Visual inspection of the pavement condition was carried out precisely by a group of trained engineers and the pavement condition index (PCI) was calculated. Control field experiments included both destructive and non-destructive (NDT) tests.