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Chip seal aggregate evaluation and successful roads preservation

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HIGHLIGHTS

- Aggregate testing is essential to ensure chip seal success.
- Chip seal application improved roadways' microtexture and macrotexture properties.
- Chip seal application reduced pavement distresses, and effectively preserved them from further cracking and deterioration.

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ABSTRACT

The Federal Highway Administration's Every Day Counts (EDC) initiative focuses on saving time, resources and money. EDC has brought infrastructure preservation to the forefront of many conversations. Chip seals are a cost-effective pavement preservation strategy, and continued studies verifying their performance benefits continue to be in high demand as agencies struggle to fund preservation programs. This study documents the effectiveness of chip seals when good materials, good construction and good agency oversight work together. Chips seals extend the service life of pavements an average of 5–6 years. This study gathers two years of field performance data (June 2014–June 2016) from chip seal projects constructed in Oregon. The data includes laboratory and field-testing to assess chip seal materials used in construction and tracks the performance of the chip seal pavements, both emulsified asphalts and hot-applied asphalts. Findings show that chip seals constructed with good quality materials enhance the surface texture properties and reduce the appearance of distresses over the two-year monitoring period for most sections.

1. Introduction

1.1. Background

Aristotle is credited with saying, "*The whole is greater than the sum of its parts*" and for chip seals, this is particularly true. Chip seal is a system of binder and chips placed in a single layer (or multiple layers) that are working together to preserve the underlying pavement structure. Chip seal aggregates, binders, existing roadway and construction conditions influence the overall chip seal performance. When all parts come together in an engineered system, the result is one of the most cost-effective ways to preserve asphalt pavements [1]. This paper summarizes the results of a study that investigated ways to improve chip seal specifications in Oregon. Throughout the project, materials used in construction met or exceeded specifications, good construction practices were followed and agency involvement occurred throughout the duration of the research; as a result, this study presents several years of data showing that with best practices, chip seals meet performance expectations and successfully preserve the road.

Roads in the US are considered major public investments. In 2007, Texas Transportation Institute released a special report documenting that poor serviceability and roadway reconstruction cost America nearly 78 billion US dollars annually by means of wasted time, services and fuel [2]. As a result, highway agencies have been interested in preserving highway investments through research and field investigations [3]. The World Bank's pavement deterioration model has further shown that the amount of money required to restore existing deteriorated pavements to their initial state costs four times more than using preventative construction methods [4]. One of the most commonly used preservation techniques is chip seal. There are many different types of chip seals, including: single chip seal, multiple chip seal, racked in seal, cape seal, inverted seal, sandwich seal and geo-textile reinforced chip seal, with the most common type being the single layer chip seal [5]. The type of chip seal used depends on the existing pavement's structural condition, roadway geometry, expected traffic volume,

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initial cost and lifecycle costs [6]. Chip seals effectively extend the pavement performance life in the following ways [7–9]:

- Reduces roadways maintenance costs
- Improves skid resistance
- Prevents water paths into the roadway substrate
- Seals cracks
- Provides anti-glare surface
- Increases the reflective surface for night and wet driving
- Reduces oxidation and aging effects

Chip seal research has advocated for performing chip seal designs prior to construction to determine the initial chip and binder application rates. McLeod design method is the most commonly used chip seal design guideline in the United States, while New Zealand design method provides the most comprehensive chip seal design guide that is used internationally. Both McLeod and New Zealand designs consider traffic and surface conditions as factors [10,11]. During design, aggregate properties such as gradation, flakiness index, specific gravity, absorption and the average least dimension (ALD) are measured. If a uniform gradation is used, the aggregate's ALD should represent the chip seal coat thickness in consideration of traffic effect on the aggregate embedment and orientation [12].

1.2. Chip seal laboratory and field investigations

Chip seal performance is greatly affected by aggregates properties, type of asphalt binder and the relative amounts of each [13,14]. The most influential properties are aggregate's size, shape, gradation, cleanliness and quality of asphalt. Chip seal design should also consider many on-site factors that affect the actual pavement performance. Research has shown that existing pavement conditions and environmental factors have the most influence on performance [8–16]. Studies have revealed that applying chip seals on poor substrate road conditions results in poor performance and a decreased expected life span [17,18]. Environmental factors that affect chip seal performance mostly include climate and weather [19].

Aggregate imaging systems (AIMS) is a laboratory-testing scheme that is considered vital for the analysis of aggregates properties. AIMS equipment takes a series of aggregate images and analyzes them using an imaging software. It is able to quantify the aggregate properties related to angularity and sphericity [20]. Such properties affect the quality of the bond between the aggregates and the binder. Masad et al. compares AIMS measurements to other commonly used aggregate analysis methods, and the research concluded that AIMS testing produces more easily utilized results that better resemble the actual field performance [21].

Field investigations are necessary to investigate chip seal performance and ensure its success. Indicators such as surface texture properties are usually manipulated to assess chip seal performance [1]. Surface texture represents both micro-texture and macro-texture properties of the pavements. Micro-texture is a function of the frictional properties of the aggregate itself, while macro texture is a function of the aggregate's size, shape, and gradation [22]. Mean texture depth (MTD) and mean profile depth (MPD) are the most widely used field measurements to represent the surface macro-texture properties. Sand circle test is usually advised to measure the MTD which follows New Zealand specifications [23]. Research has shown that sand circle test is equivalent to sand patch test which follows ASTM E965 [24]. Dynamic friction test (DFT) is commonly used to represent the surface micro-texture properties by measuring the coefficient of friction.

1.3. Pavement condition assessment

Pavement condition assessments are utilized to quantify pavement performance over time. Pavement condition is primarily assessed based upon apparent distresses [25]. Distresses are usually investigated visually and/or quantitatively. Primary structural distresses include fatigue cracking (alligator cracking), longitudinal cracking and transverse cracking. Representative sample roads are usually selected at various traffic volumes and underlying conditions and related data is collected, processed and analyzed for different years to be used for future performance evaluation and planning. Chip seal predominant related distresses are oxidation, aggregate wear, aggregate polishing, bleeding, and aggregate loss [26].

Distress surveys have been one of the most common ways to evaluate overall chip seal performance. Some agencies have established visual performance criteria for chip seal performance evaluation. Some criteria include [27]:

- Chip seal surfaces should have minimal tears and streaks
- Joints should be neatly constructed and free of any built up or irregularities
- Longitudinal joints should have no more than a 2 in. (50 mm) overlap
- Edges should be neat and free of irregularities
- A maximum variance of 2 in. (50 mm) per each 100 feet (30.5 m) is permitted

1.4. Objectives and scope

The objective of this research is to build and expand on the existing research that advocates for quantitative test results. The paper provides data to establish straightforward field measurements that provide an indication to chip seal performance. A 2014 project in Oregon with eight chip seal roadways was studied to evaluate pavement performance using: (1) laboratory testing, (2) field testing and (3) performance monitoring.

Aggregate testing is intended to validate the materials used and make sure that they are meeting specifications, and are of proper quality. Laboratory tests conducted in this study are: (1) gradation, (2) flakiness, (3) abrasion resistance, and AIMs testing. AIMS laboratory testing was used to assess the angularity and sphericity properties, which are essential for chip seal.

Field-testing included measurements of MTD and friction parameters using sand circle test (TNZ T/3:1981) and dynamic friction test (ASTM E670 – 09: 2015). Pavement performance surveys evaluated pavement distresses before chip seal application, immediately after seal application, after one year and two years of traffic/in-service life. Pavement distresses evaluated are transverse cracking, longitudinal cracking, fatigue cracking, pothole, patching, bleeding, loss of aggregate and rutting. Analysis was performed to compare between different test sections' performance.

2. Project overview

The project included in this study was constructed in 2014 and is located in the state of Oregon. Table 1 summarizes the different test sections (denoted as units A to H) with their relative information such as: location, binder types, traffic flow (annual average daily traffic AADT) and initial road condition. Binder types includes polymer modified emulsified asphalt (CRS-2P) and polymer modified hot applied asphalt (AC-15P). Traffic flow represented both low volume traffic roads with less than 500 AADT, and high volume traffic roads with more than 500 AADT. Existing pavement condition varied from very poor to good based upon Oregon DOT