# A CAPITAL PAVEMENT PRESERVATION PROGRAM FOR RURAL ROADS SUSTAINABILITY

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## ABSTRACT

Mohave County, Arizona maintains a new Capital Pavement Preservation Program (CPPP) to identify, rank, schedule, and budget for the structural rehabilitation of County hard surfaced roads, which approach an end to structural service life. It facilitates diligent programming of capital projects with limited funds to sustain the County's extensive rural road network. This paper presents the technical basis of program development encompassing an engineering-based assessment of pavement structural stability using available County and published traffic and soils data. Program structure development entails establishing discrete road study sections with uniform (re)construction year, determining roadbed soil classification for estimating in-situ material stiffness, and assessing cumulative traffic load since (re)construction. Program findings and critical needs recommendations draw on practical analyses, which include (1) determining a Design Structural Number (DSN) from composition and thickness of pavement structural section layers comprising road study sections and (2) calculating a comparative Operational Structural Number (OSN) using synthesized data on cumulative traffic load and roadbed soil stiffness. The resulting measure of structural stability, OSN to DSN, constitutes the base CPPP technical criterion for pavement rehabilitation project selection and enables road network sustenance through an engineered approach designed for practical and efficient application to support long-term CPPP administration.

## 1. INTRODUCTION

Rural Mohave County, Arizona (2010 population: 200,186) maintains 1,272 centerline kilometers of hard surfaced roads throughout a geographic area totaling 34,478 square kilometers. It represents the fifth largest county by land area in the contiguous United States. The County witnessed its network of regional highways take form beginning in the 1960s and expanding through the 1980s as a result of the construction of new or realigned interstate and State highways, which caused Mohave County to take operation and maintenance of select sections of previous national and State highways. These routes remain important arterial roads connecting County population centers.

In the past 30 years, Mohave County has realized a quadrupling of its population and further expansion of its road network. Growing residential and commercial development outside incorporated cities fuelled construction of new collector and arterial roads providing essential connection to State and County highways. Meanwhile, the County continually facilitated the improvement of unpaved regional roads, many following historic alignments established by area settlers in the late 1800s and early 1900s, to a hard surface condition in response to increasing traffic loads. Improvement projects ranged from traditional hot-mix asphalt over aggregate base course to placing chip seal over stabilized subgrade. Collectively, these projects produced an aesthetically similar roadway surface, as shown in Figure 1, and provided like rideability conditions to motorists.

Figure 1 – Chip Sealed Road over Stabilized Subgrade

Mohave County employs a dedicated pavement preservation program inclusive of routine but largely non-structural crack seal, chip seal, and thin overlay applications based on annual roadway surface condition inspections and engineering recommendations. Though most hard surfaced roads countywide function as low-volume roads, an engineered approach toward identifying, ranking, and scheduling for the structural rehabilitation of County highways, arterials, and select collector roads is necessary in recognition of declining structural sufficiency of existing roads, many in service over 20 years since last (re)construction. This aligns with a focus on preserving existing road infrastructure assets under current economic conditions.

This paper presents a macro-level, engineered approach toward developing a new Capital Pavement Preservation Program (CPPP) to proactively plan for structural rehabilitation of existing County hard surfaced roads and improve network-wide structural sufficiency. The basis of this transferable approach recognizes roadbed native soil strength and stiffness as a significant parameter influencing the long-term performance of any road pavement structure. National soil surveys published through a relatively new geographic information system (GIS) delivery method enables the County to access and analyze available soil classifications for engineering interpretation of soil performance characteristics on a network-wide level. The quantity of soils information needed proves cost prohibitive under a data collection approach based on field sampling only. On a significantly lessor scale, such manual methods easily input into the CPPP approach. Using defined roadbed soil parameters describing in-situ material stiffness, the CPPP approach applies standard pavement evaluation methods to evaluate design versus remaining structural strength for facility-specific pavement structural section layer composition, thickness, and age coupled with cumulative traffic load serviced.

## 2. METHODOLOGY

The Capital Pavement Preservation Program approach evolves from the design of a previous study by Mohave County performed for the purpose of examining results of roadway surface inspections for roads improved from an unsurfaced to hard surfaced condition through the County's soil stabilization program from 2003 to 2007. During this time, the County developed 102 kilometers of hard surfaced roads improved either through (1) chip seal surface treatment over chemically stabilized roadbed or (2) chip seal over asphalt millings, comprised of fine to gravelly particles of bitumen and inorganic material. A 2009 annual inspection of roadway surface condition, including structural and non-structural distresses and undulations, indicates 67 percent of all soil stabilized roads exhibited good surface condition while 16 percent showed poor condition.

The soil stabilization study considers roadway surface condition deterioration as attributed to traffic load, environmental effects, and load-carrying capacity of native soils comprising the underlying roadbed. It focuses on effects of native soil strength and stiffness by incorporating technical information and data contained in United States National Resources Conservation Service (NRCS) published soil surveys available in a GIS application, the NRCS Web Soil Survey [1]. Using spatially referenced ratings on soils performance for road construction, investigated by NRCS and included in soil taxonomy descriptive data, the Mohave County study found, with statistical significance, that native soil properties of strength and stiffness positively correlate to roadway surface condition. This finding influences the County's initiative toward incorporating technical information and data on roadbed native soils in developing its Capital Pavement Preservation Program and, in particular, estimating remaining pavement structural life and determining pavement treatments supporting structural preservation or rehabilitation for a range of conditions as illustrated in Figure 2.

Figure 2 – Regional Highways in CPPP Assessment

## 2.1. Analysis Procedure

Mohave County adopts the American Association of State Highway and Transportation Officials (AASHTO) *Guide for Design of Pavement Structures*, 1993 Edition, as its pavement structural design policy [2]. Required input data for CPPP assessment follows AASHTO criteria for flexible pavement structural design procedures in determining structural number. Parameters encompassing traffic load, roadbed soil stiffness, service life, and pavement structural section layer depth and composition factor into this analysis procedure. It necessitates an initial step of establishing discrete road sections for individual analysis where each section has a uniform origin year of last hard surface construction or reconstruction, is continuous, and has a maximum centerline distance of approximately 16 kilometers as established for analysis purposes. In certain instances, road study section termini reference an easily identifiable intersection.

Roadbed soil stiffness represents an input parameter central to the CPPP analysis process and the most expansive to estimate when demanding accurate soil property and quality descriptions. Laborious soil sampling and testing methods fail to efficiently generate the plethora of data needed to estimate with reasonable precision the classification of native soils underlying any road section. The NRCS Web Soil Survey fills the gap in this regard, providing GIS-based access to soil boundaries and descriptions as queried within user-defined spatial areas. These queries include hundreds of kilometers of roads included in the CPPP assessment. The published NRCS soil surveys delivered through Web Soil Survey contain engineering-based soil classifications, reporting both Unified Soil Classification (USC) and AASHTO classification system categories, for survey identified soils. The NRCS National Soil Survey Handbook details the operational policy and guidance employed to define, collect, test, and denote the breadth and depth of soil property and feature descriptions packaged in NRCS soil surveys [3].

The cited maximum centerline distance for establishing road study sections considers the cumulative increase in soil classification variability with increasing roadbed area as minimizing such variability proves beneficial in determining a single estimate of soil stiffness from a corresponding roadbed soil classification category. Numerous publications in the literature provide soil stiffness estimates corresponding to USC and AASHTO soil classification categories. These values, when adjusted to represent resilient modulus, input into the AASHTO structural design policy applied to CPPP analysis for structural number calculation. The procedure references USC system category values in estimating roadbed soil stiffness as NRCS soil survey property tables do not report AASHTO classification system group sub-classifications. Commonly, a single soil composition type such as gravelly, sandy, or silty/clayey dominates the characterization of roadbed soils in sections spanning a few kilometers or less.

Historical traffic volume and vehicle classification data enter into computations of cumulative traffic load since pavement construction or last structural rehabilitation as indicated by road study section origin year. Cumulative traffic load gauges relative impact on road section structural service life exclusive of desert ambient and other ancillary effects common to the overall study network.

### 2.2. Structural Stability Performance Measure

CPPP development and management requires a clear and practical performance measure central to characterizing the health of County roads assessed under the program. This measure represents a relationship between two parameters describing pavement structural number. One parameter changes over time as it incorporates cumulative loading on a pavement structure since its (re)construction. The Operational Structural Number (OSN) applies the AASHTO flexible pavement structural design procedure to estimate, using available field and published traffic and soils data, the effect of traffic load to roadbed soil quality from (re)construction year to the present. The other parameter remains static and denotes the Design Structural Number (DSN), which defines the total structural number for all pavement structural section layers comprising any road study section. DSN considers composition, thickness, and structural coefficient of each pavement layer as (re)constructed and serves as an indicator of pavement structural capacity established at (re)construction.

The structural stability performance measure provides an indicator of remaining pavement structural life, using DSN as its baseline. Structural stability can take the form of a ratio or difference between OSN and DSN to express remaining structural life. Increasing pavement structure age, cumulative traffic volume, and cumulative heavy vehicle count promotes an increasing OSN, which impacts remaining structural life. The term structural stability suits this performance measure by packaging effects of structural loading, roadbed soil strength and stiffness, and (re)constructed pavement composition into a single performance measure for analysis and end user decision-making purposes.

## 3. APPLICATION

The Capital Pavement Preservation Program includes 496 road centerline kilometers, representing regional highways, intra-place arterials, and major collectors. CPPP assessment considers 217 road study sections, each continuous and established on basis of uniform route, pavement structural section, and origin year of last hard surface (re)construction. Sections average 2.3 centerline kilometers in length and range from 129 meters to 11.3 kilometers. This task facilitates consistency in performing structural number calculations toward estimating structural stability. Roadbed soil composition remains an underlying variable, but the range of soil type and corresponding stiffness narrows with reduced section lengths. Project programming benefits from this detailed approach so that structural rehabilitation treatment selection may consider a range of structural stability measures within a corridor of multiple study sections.

### 3.1. Analysis Performance

The next task involves identifying section-specific data on roadbed soil stiffness, traffic volume and composition, and pavement structure composition and layer thickness. These variables input into subsequent structural number calculations. Mohave County maintains a comprehensive traffic count program and asset management database, which collectively provides data supporting OSN and DSN calculations. Traffic load calculations reference and extrapolate as necessary historical automatic traffic recorder counts collected since study section (re)construction. Pavement structural section descriptions derive from certified as-constructed plans as well as pavement core samples, illustrated in Figure 3. In the absence of ongoing programs, similar assessments may initiate field studies as necessary to record average daily traffic, percent heavy vehicles including buses and trucks, and pavement surface and base layer information.

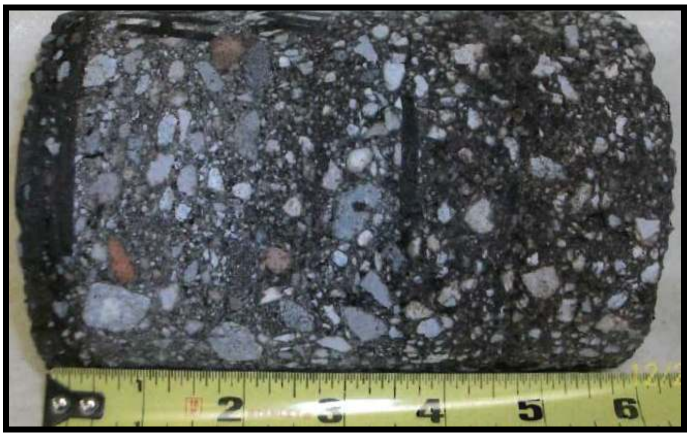

Figure 3 – Sample Core Showing Flexible Pavement Surface Layer

The NRCS Web Soil Survey provides GIS-based, soils data inclusive of engineering-based soil classifications for estimating soil stiffness. The Web Soil Survey precludes extensive and costly field investigations and laboratory testing to reasonably quantify the roadbed soil stiffness parameter essential to CPPP assessment. The process entails defining an area of interest in the form of a closed polygon coincident to study section geographic location and boundaries. This permits query of the latest available NRCS soil survey(s) encompassing the area of interest coupled with spatial display of data on surface soil properties and qualities as selected by the user. Figure 4 shows a query result for an example road section. This CPPP analysis step assigns a single Unified Soil Classification category to an individual road study section. Where study sections contain soils categorized under multiple USC categories, the section receives a category corresponding to the 25$^{th}$ percentile level of total area within the queried area of interest.

Structural stability calculation follows input data compilation for each study section as detailed. Operational Structural Number determination applies the AASHTO flexible pavement structural design procedure to an analysis time period from last (re)construction to present compared to the procedure's typical application to forward-looking design periods. In turn, cumulative traffic load under the analysis period incorporates measured versus forecast values. This procedure requires numerical values for roadbed resilient modulus, which numerous correlation charts appear in the literature for all USC categories assigned to the study sections. Solving for OSN follows by applying the AASHTO equation or nomograph for this procedure and referencing criteria values for reliability, standard deviation, and serviceability loss on basis of road study section functional class, specifically secondary arterial and collector roads.

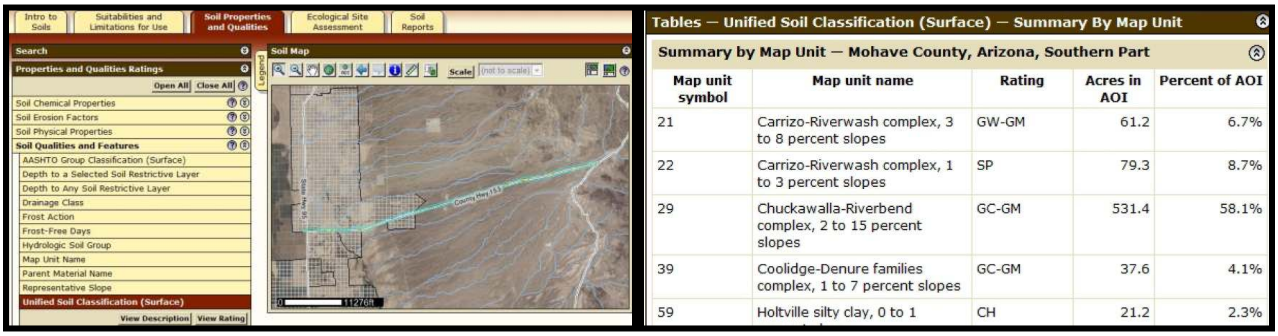

Figure 4 – Spatial Query in Web Soil Survey for Roadbed Soil Classification [1]

Design Structural Number determination takes the sum of all pavement structural layers, non-native or treated, comprising a study section. Numerous publications in the literature provide pavement structural layer coefficient values for various layer compositions [4]. The product of layer coefficient and as-constructed thickness inputs into overall DSN for each road study section. This task considers a plethora of pavement layer types inclusive of common flexible pavement course materials. For instance, chemically stabilized sections establish a dedicated pavement structural layer for the stabilized roadbed with thickness equivalent to the depth of treated and compacted native or fill material.

Poorer quality soils correlate to increased OSN value and reduced measure of structural stability. DSN does not factor roadbed soil stiffness in contrast to the OSN calculation procedure. This deserves careful consideration when assessing and ranking road study sections in accordance with structural stability performance measure values. Generally, sandy coarse grained soils may provide double the performance capacity of silty/clayey fine grained soils, and gravelly coarse grained soils may quadruple that capacity. If considering roadbed soils distributing traffic loads to depths of 30 centimeters, the quantitative effect to DSN of roadbed soil type from poor to good may expand to as much as a structural number value of one.

## 3.2. Analysis Findings

The Capital Pavement Preservation Program assessment indicates 80 percent of all 217 road study sections may have reached or surpassed pavement structural section service life. This finding does not adjust DSN for roadbed soil effects. The average structural stability performance measure for all sections suggests the collective road network has exceeded its baseline service life, as established by the Design Structural Number, by 81 percent. The OSN averages 2.02 and ranges from 1.20 to 4.24. The OSN average falls short of structural numbers commonly applied in flexible pavement design for new projects, but this reflects low cumulative traffic loading on the road network when considering the age of road study sections since last pavement structural section (re)construction average 16 years. The DSN varies from 0.30 to 3.38 with a mean of 1.42, representative of many hard surface roads featuring a relatively thin pavement structural section akin to serving a low-volume traffic environment.

Most road study sections lie on coarse grained native foundation soils. This includes 42 percent and 40 percent on gravelly and sandy roadbed soils, respectively. Structural stability declines in step with poorer foundation soils. The assessment finds this measure of OSN to DSN at 1.66, or two-thirds above baseline service life, for study sections with gravelly roadbeds, 1.86 for sandy roadbeds, and 2.04 for silty/clayey roadbeds. Recognizing better subgrade performance provided particularly by clean coarse grained soils, CPPP project priority rank and treatment selection must evaluate structural stability measures with roadbed soil type considered among other decision criteria such as pavement surface condition, functional class, and use.

## 4. CONCLUSIONS

This paper presents an efficient and adaptable methodology toward obtaining a snapshot of road network structural serviceability. It supports a Capital Pavement Preservation Program enabling sustainable maintenance of rural roads by enhancing the level of due diligence assessment performed to optimally identify, scope, and schedule pavement rehabilitation projects and provide for the best use of available capital funds. Availability of roadbed soils information drives the application and ease thereof of this methodology. Its approach may transfer to facilitate agency standards and policy on pavement rehabilitation and new construction. For example, establishing minimum specifications on pavement layer thickness indexed to subgrade soil condition under a range of design traffic load and/or road functional class thresholds. The overarching goals in any application context concerns right sizing and right timing improvements to maximize investment benefit.

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