CREATION AND DEVELOPMENT OF PAVEMENTDESIGNER.ORG – A UNIFIED INDUSTRY-WIDE PAVEMENT DESIGN TOOL FOR CONCRETE AND CEMENT-BASED SOLUTIONS

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ABSTRACT

Obstacles have been identified on the further use of concrete and cement-based pavement solutions in city, county, and other non-federal or state level markets in the United States. Decision makers that work in these smaller agencies usually perform multiple tasks, often requiring a less time-intensive decision method. When faced with pavement design and selection, these engineers tend to repeat past designs without serious consideration of concrete or cement-based solutions. Numerous design tools are available today contributes to a general perception that designing concrete pavement is difficult. To address this challenge, the American Concrete Pavement Association (ACPA), along with industry partners, the Portland Cement Association (PCA) and the National Ready Mixed Concrete Association (NRMCA), have collaborated to develop one industry recommended pavement design tool for non-state agencies. The new tool combines existing best design practices for jointed and continuously-reinforced concrete pavements, overlays, roller-compacted concrete, and cement-treated subbases, bases, and soils. The tool is web-based and designed to be easy to use, addressing the perception of complexity, as well as the time it takes to design concrete solutions. This paper details the needs, describes challenges in the design process, and documents the existing methodologies used to create the new tool.

KEYWORDS

THICKNESS DESIGN / PAVEMENT DESIGN / PAVEMENTDESIGNER.ORG. / AASHTO 93 / AASHTOWARE PAVEMENT ME / CONCRETE STREET DESIGN

1. INTRODUCTION AND BACKGROUND

One of the most essential steps in designing and building a pavement is the pavement thickness design process. The thickness design will drive the pavement type selection and the life-cycle cost analysis, which agencies and decision-makers use to determine what type of pavement structure will be utilized for a roadway.

Pavement thickness design in the United States is typically broken into three fundamental types: mechanistic, empirical, and mechanistic-empirical. Mechanistic designs are built on the mechanics of the materials. This typically takes the form of a finite element analysis (FEA) or model (FEM). Empirical designs are based on observations. This type of design is typically based on a test road or test sections, where the pavement's performance is monitored over time and characterized to predict how future designs will perform. A mechanistic-empirical (ME) design is a combination of the first two design methods. The mechanics of the materials are used to model and predict performance, and test sections are built and monitored to tie the predicted performance back to actual field performance. ME design is typically the best and most robust pavement design methodology.

Within the United States, many pavement design tools have been developed that would fall into one of the previously mentioned categories. Mechanistic tools such as the finite-element programs I-SLAB (Khazanovich, 2000) and EverFE (EverFE, 2006) exist to assist in modeling concrete pavements. These are typically used for analyzing a given scenario rather than performing a pavement design. One of the most common pavement design methodologies is the empirical based American

Association of State and Highway Transportation Officials' (AASHTO) Guide for Design of Pavement Structures (simply known as AASHTO 93) design guide. Perhaps the most robust design methodology currently available is AASHTOWare's Pavement ME Design (Pavement ME), which is a mechanistic-empirical design that's been built over the course of nearly 20 years with data collection from hundreds of test sections (called Long-Term Pavement Performance (LTPP) sections.

1.1 Highway and Roadway Pavement Design

These design methodologies have many benefits (model various scenarios, have robust feedback, numerous design parameters), but also have drawbacks (ease of use, data required, cost, realistic/cost-effective designs). Perhaps the biggest drawback is that most are not applicable over a wide range of facilities. Two of the most common design methodologies in the US are AASHTO 93 and Pavement ME, which were both designed for federal and state highways, and not built for local and county roads, parking lots, or industrial and intermodal facilities with vehicles that don't have over the road tires.

The AASHTO 93 design method (AASHTO, 1993) is also built off the AASHO Road Test, which was performed between 1958 and 1960 in Ottawa, Illinois (Highway Research Board, 1961). The test was performed with limited variety in concrete materials, support materials, and with little variation in construction techniques. Another limitation is that the pavements were only subjected to two years of environmental loading and no faulting/erosion observations were recorded and built into the design. At the end of the test, most of the concrete pavement sections had not failed, and performance had to be projected for anything beyond the limited amount of loading the pavement endured during the testing.

Because of these limitations and the need for a better design, AASHTO developed the Mechanistic-Empirical Pavement Design Guide (AASHTO, 2004). This design guide evolved over the years into the current version, AASHTOWare's Pavement ME Design (AASHTO, 2017). The intent is to continually improve the tool set with further research and test section performance. The tool allows users to characterize many aspects of the pavement, environment, materials, and traffic to best model the pavement and predict future performance. The predicted performance is characterized by cracking, faulting, and international roughness index (IRI), or ride, for jointed plain concrete pavements (JPCP). The main drawbacks of the tool are that it is expensive (single user license is $5,500 USD as of 2017) and highly detailed, as nearly 1,000 inputs are required to fully characterize the pavement and predicted performance. This is typically a hinderance on local engineers who have limited time to spend on pavement design or who do not design pavement frequently.

1.2 Parking Lot & Intermodal/Industrial Pavement Design

As previously mentioned, the AASHTO design methodologies are developed for federal and state facilities. While they have been frequently used for roadway designs for cities, counties, and other facilities, they are more difficult and less relevant to apply to facilities with slow moving and heavy vehicles or vehicles with unique loading scenarios.

Parking lot design has been handled using the AASHTO 93 design methodology, but due to the drawbacks previously mentioned, it oftentimes leads to designs that are overly conservative and not optimized. The only primary design guide developed strictly for concrete parking lots is the American Concrete Institute's (ACI) 330R-08 Guide for the Design and Construction of Concrete Parking Lots (ACI, 2008). This is a design document developed by ACI. The design of pavements in this document is handled through the use of design tables where the user can select details on their support condition, traffic loading, and concrete material properties. This simplifies the design, but doesn't allow users a lot of options for optimization of the design. The guide is developed based on design runs of the American Concrete Pavement Association's (ACPA) previous design tool, StreetPave 12 (ACPA, 2012).

The design of intermodal and industrial facilities is another challenging scenario. Oftentimes these facilities have extremely heavy loads, non-channelized traffic, and unique loading conditions (e.g. forklifts, cranes, agricultural equipment, etc.). Oftentimes, these facilities cannot be designed with AASHTO methods due to the unique loadings and use of off-road tires. ACI has recently developed a guide that addresses some of these facilities, the ACI 330.2R-17: Guide for the Design and Construction of Concrete Site Paving for Industrial and Trucking Facilities (ACI, 2017). This is similar to the ACI 330R-08 guide in that its primary design method is based on design tables. It does mention that other design tools can be used. Two of those tools are ACPA's StreetPave 12 and ACPA's AirPave 11 (a tool originally made for the design of airfield concrete pavements).

1.3 Other Design Tools

Beyond the design tools previously mentioned, there are additional tools and guides. Some are older design guides from ACI. Others are earlier versions of AASHTO 93 such as the AASHTO 1986 Guide for Design of Pavement Structures (AASHTO, 1986), and the original AASHTO 1972 Interim Guide for Design of Pavement Structures (AASHTO, 1972). Many of these guides are outdated, but some survive and are used by designers who do not know newer and more relevant versions exist. Additionally, industry-developed tools such as Pervious Pave, WinPAS, Concrete Pavement Analyst, PCA-Pave, and RCC-Pave, exist for a variety of specific applications such as pervious pavements, parking lots, composite pavements, and roller-compacted concrete (RCC) pavements.

1.4 A Unified Design Approach

In 2015, the concrete pavement industry, including ACPA, the National Ready-Mix Concrete Association (NRMCA), and the Portland Cement Association (PCA), decided to address the drawbacks of some of the existing tools for the design of concrete pavements. The industry also decided to consolidate the various design tools to reduce and eliminate confusion as to which design approach is best for each individual application and when certain designs are or are not applicable.

The concrete pavement industry began development on a single tool for the design of concrete pavements and other cement-based pavement systems in 2016. This will serve as the concrete pavement industry's recommended design methodology for all facilities that are not covered by AASHTOWare's Pavement ME Design, which the industry recognizes as the best tool for highways and other Federal and State roadways.

PavementDesigner.org, or simply PavementDesigner, was selected as the name of the industry's design tool. To make PavementDesigner easy to use and readily accessible, the industry agreed to make it web-based and free to all users. This paper details the development of PavementDesigner, the design methodologies implemented within the tool, the new features developed for easing design, and future updates that may be implemented.

The structure of this paper will go through PavementDesigner's street design (including JPCP, RCC, continuously-reinforced concrete pavement [CRCP], overlays, and composite pavements [with cement-altered support layers]), parking lot design, and intermodal pavement design.

2. PAVEMENTDESIGNER'S STREET DESIGN

PavementDesigner's street design allows for the design of full-depth concrete (JPCP, RCC, and CRCP) roadways as well as overlays and composite pavement sections with cement-altered support layers. The selection screen for these options can be seen in Figure 1, below. Each design follows a three-tiered design procedure that includes "Project Level" details, "Pavement Structure" details, and a pavement design "Summary."

Figure 1 – PavementDesigner's street project type selection screen

2.1 PavementDesigner's Jointed Plain Concrete Pavement (JPCP) Design

PavementDesigner's JPCP design methodology is originally based on the 1960's PCA Method (PCA, 1966). This methodology was used for ACPA's StreetPave 12 (ACPA, 2012) design program. The design methodology includes two failure modes: fatigue and erosion. Fatigue predicts the amount of cracking at the end of the pavement's life. The fatigue model is based on calculating a stress and relating that to the concrete's strength. Control of this stress ratio (SR) is done by increasing or decreasing the pavement's thickness to arrive at an allowable number of trucks greater than the predicted number of trucks over the design life. Erosion characterizes the faulting that may develop over the pavement's life. This model was developed in the 1980's (PCA, 1984) using field data from five states all over the U.S.

The first input level of full-depth concrete street design is the "Project Level" details which characterize the traffic the pavement will be subjected to over it's life and the failure criteria (such as the Design Life, Reliability, and Percent Slabs Cracked at the end of the design life). This can be seen in Figure 2. The traffic inputs can be characterized directly by inputting the trucks per day, linear traffic growth rate, directional distribution of trucks, and design lane distribution of trucks. These inputs are used to calculate the average trucks per day in the design lane over the design life and the total trucks in the design lane over the design life. The trucks are distributed over a traffic spectrum to define the axle weights of all the trucks rather than by designing by equivalent single axle loads (ESALs) as AASHTO 93 does. PavementDesigner has 8 default traffic spectrums (number of axles/1000 trucks at a given axle load) for all types of facilities (residential, collector, minor arterial, major arterial, and four ACI traffic categories [A-D] defined in ACI 330's design guidance) and allows a custom traffic spectrum to be input as well.

The traffic can also be estimated based on an existing asphalt pavement design. Utilizing the details of the pavement design with thickness and layer coefficients, and additional inputs including the subgrade resilient modulus, serviceability, initial and terminal serviceability, the structural number (SN) and allowable flexible ESALs can be calculated based on AASHTO 93's flexible pavement design procedure. Utilizing the selected traffic spectrum (along with the corresponding weights and load equivalency factors [LEFs]), the allowable trucks over the design life in the design lane and allowable trucks per day in the design lane are calculated. This method of calculating the traffic is an update from the design methodology as it is featured within StreetPave 12.

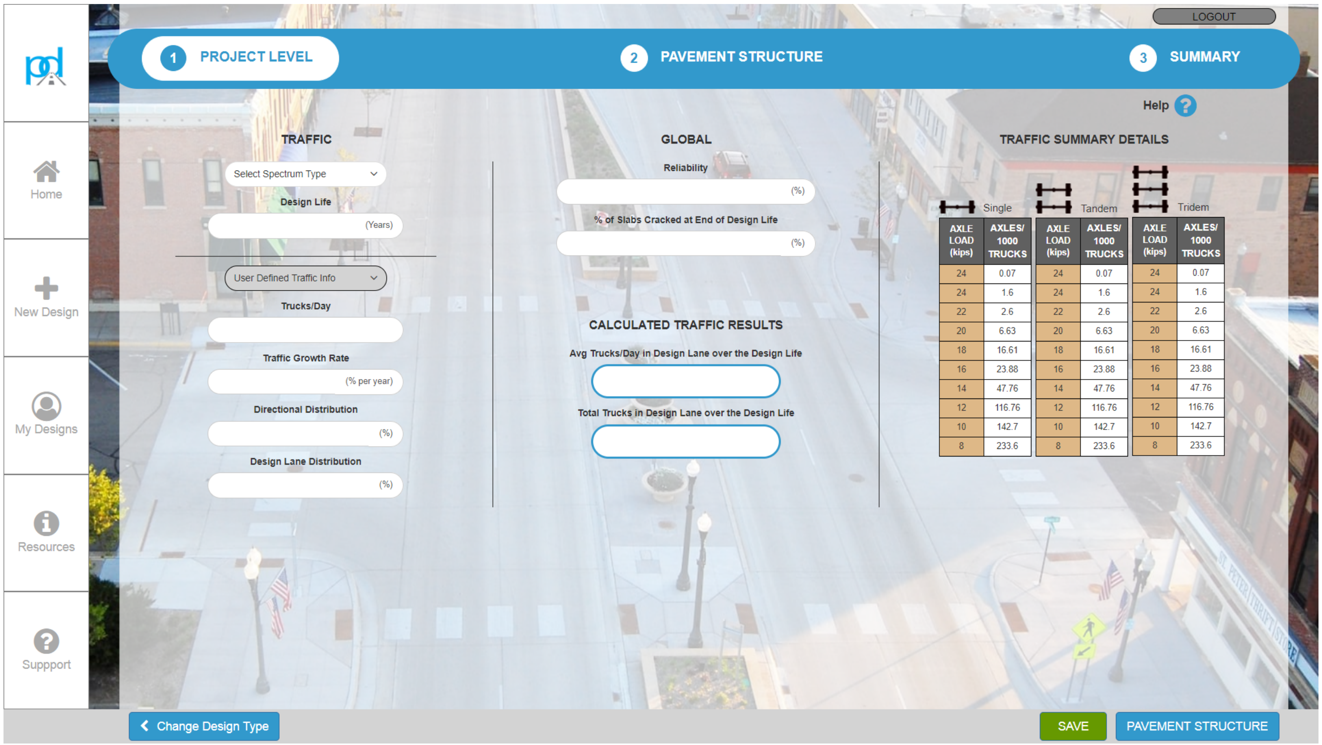


Figure 2 – PavementDesigner's "Project Level" design screen for JPCP design

The "Pavement Structure" details are the next input level and can be visualized in Figure 3. This section characterizes the subgrade (via resilient modulus of the subgrade [MRSG]). This value can be estimated from a California Bearing Ratio (CBR) or a resistance value (R-Value) using built in conversions based on conversions published as NCHRP Project 128 (NCHRP). The concrete material is also characterized by the modulus of elasticity (E), and 28-day flexural strength or modulus of rupture (MOR), which can be estimated using built-in calculations from the compressive strength (Mindess, et al. 2003), split tensile strength (Narrow and Ulbrig, 1968), or modulus of elasticity (ERES, 1987). Finally, structure or subbase layers are defined by a resilient modulus and thickness of each layer. These inputs combined with the MRSG are utilized to calculate the composite K-Value of the substructure utilizing a conversion originally developed for StreetPave 12 (ACPA, 2012) and is detailed in WikiPave (2017). The calculated composite K-Value can be overridden with a user-defined composite K-Value. Below are the equations for the strength conversions to flexural strength (MOR):

$$\text{Flexural Strength (psi)} \;=\; 2.3 * (\text{Compressive Strength})^{2/3} \qquad (1)$$

$$\text{Flexural Strength (psi)} \;=\; \text{Spit Tensile Strength} + 250 \qquad (2)$$

$$\text{Flexural Strength (psi)} \;=\; \frac{\textit{Modulus of Elasticity}}{2.3 * 10^4} + 488.5 \qquad (3)$$

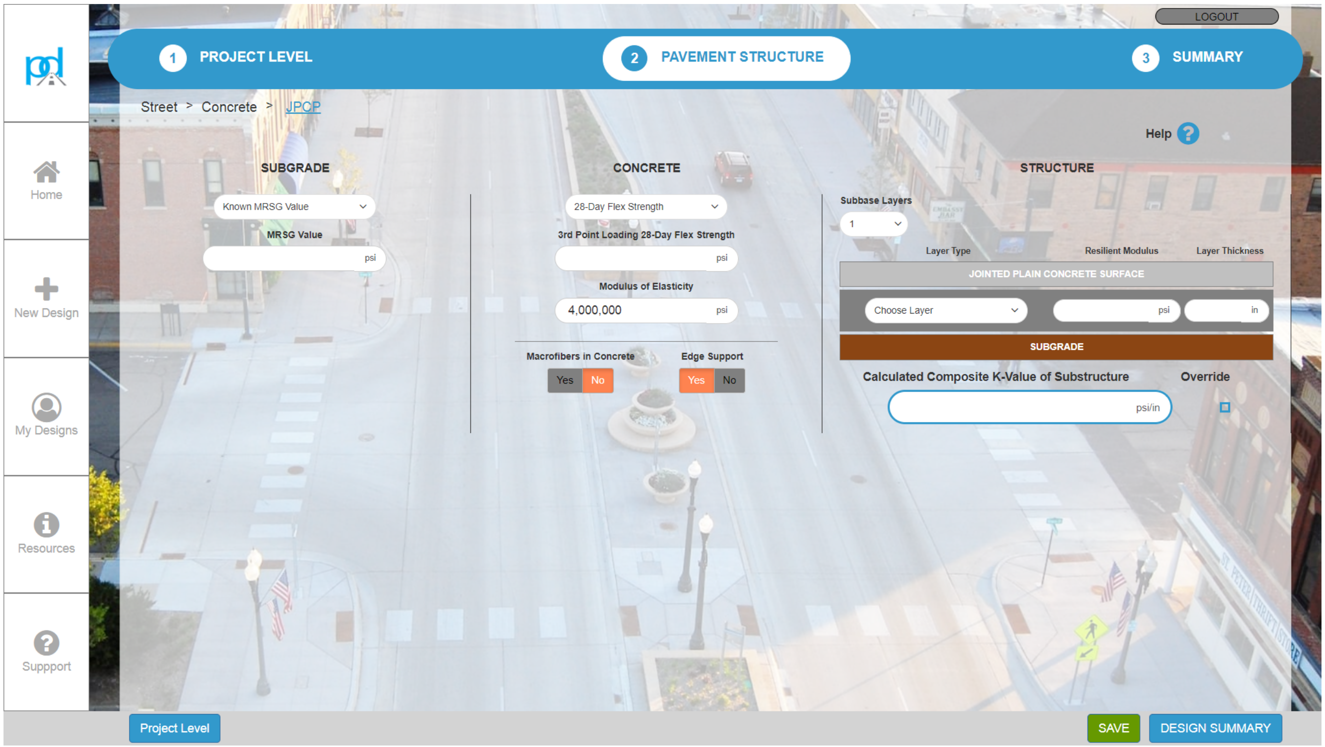


Figure 3 – PavementDesigner's "Pavement Structure" design screen for JPCP design

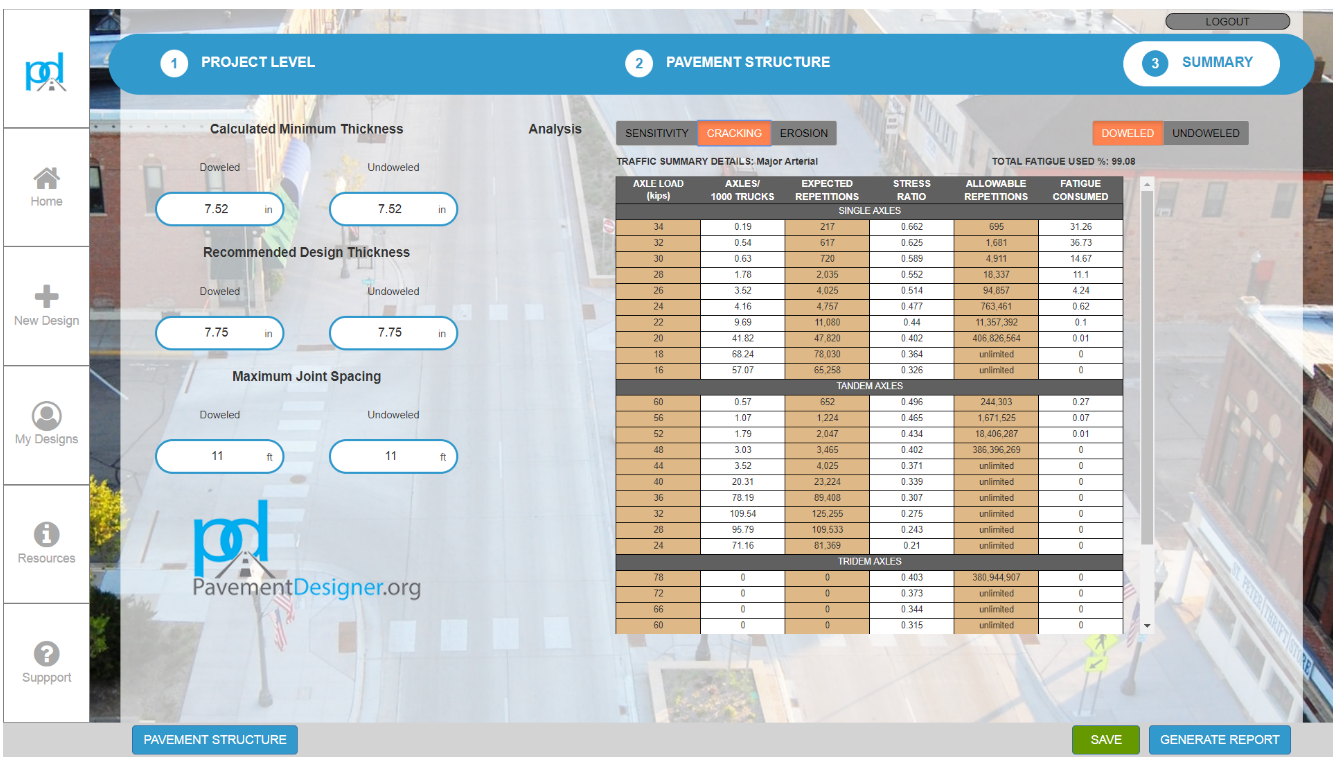
Figure 4 – An example of PavementDesigner's design "Summary" for JPCP design

With all design parameters characterized, the user can proceed to PavementDesigner's "Summary," shown in Figure 4, where the "Calculated Minimum Thickness" and "Recommended Design Thickness" are reported, along with the "Maximum Joint Spacing." All these values are reported for both dowelled and undowelled scenarios. The calculated minimum thickness represents the smallest thickness required to carry the trucks defined in the “Project Level” details and is the same as the calculation used within StreetPave 12. The “Recommended Design Thickness” takes the “Calculated Minimum Thickness” and rounds up to the next quarter inch for the sake of constructability. The “Maximum Joint Spacing” is calculated using the equation below:

$$JS = 4.5l = 4.5\sqrt[4]{\frac{Eh^3}{12(1-\mu^2)k}} \tag{4}$$

where JS is the maximum joint spacing (ft), l is the radius of relative stiffness (in), E is the modulus of elasticity of the concrete (psi), h is the recommended design thickness (in), μ is the poisson’s ratio of concrete (assumed to be 0.15), and k is the composite k-value of the substructure (psi/in). This joint spacing calculation and the alternate way of defining traffic based on an existing asphalt design are the only major deviations/updates to the StreetPave 12 design methodology that are incorporated into PavementDesigner for the JPCP design process.

From the “Summary” of the design, a pdf report can be generated displaying all the information on the pavement design. The “Summary” also includes sensitivity plots, and cracking and erosion tables. The sensitivity plots show the impact on the calculated thickness as design parameters (K-Value, flexural strength, design life, reliability, and percent slabs cracked) are varied, which can help optimize a design. The cracking and erosion tables can help a designer determine which failure mode is controlling the design and whether or not a single axle type is causing most of the damage. A sample fatigue table can be seen in Figure 5.



AXLE LOAD (kips)	AXLES/ 1000 TRUCKS	EXPECTED REPETITIONS	STRESS RATIO	ALLOWABLE REPETITIONS	FATIGUE CONSUMED
SINGLE AXLES					
34	0.19	217	0.662	695	31.26
32	0.54	617	0.625	1,681	36.73
30	0.63	720	0.589	4,911	14.67
28	1.78	2,035	0.552	18,337	11.1
26	3.52	4,025	0.514	94,857	4.24
24	4.16	4,757	0.477	763,461	0.62
22	9.69	11,080	0.44	11,357,392	0.1
20	41.82	47,820	0.402	406,826,564	0.01
18	68.24	78,030	0.364	unlimited	0
16	57.07	65,258	0.326	unlimited	0
TANDEM AXLES					
60	0.57	652	0.496	244,303	0.27
56	1.07	1,224	0.465	1,671,525	0.07
52	1.79	2,047	0.434	18,406,287	0.01
48	3.03	3,465	0.402	386,396,269	0
44	3.52	4,025	0.371	unlimited	0
40	20.31	23,224	0.339	unlimited	0
36	78.19	89,408	0.307	unlimited	0
32	109.54	125,255	0.275	unlimited	0
28	95.79	109,533	0.243	unlimited	0
24	71.16	81,369	0.21	unlimited	0
TRIDEM AXLES					
78	0	0	0.403	380,944,907	0
72	0	0	0.373	unlimited	0
66	0	0	0.344	unlimited	0
60	0	0	0.315	unlimited	0

Figure 5 – An example of PavementDesigner’s fatigue table for JPCP design

2.2 PavementDesigner’s Roller-Compacted Concrete (RCC) Pavement Design

PavementDesigner can also be used to design RCC pavements. The RCC design is the same as the design procedure for JPCP with one major exception. The RCC design procedure only designs the pavement as an undowelled section. This is due to current construction limitations that do not allow dowels to be placed within RCC pavements.

The RCC design module was decided to follow the undowelled JPCP design based on recommendations from ACPA's pavement design and RCC task forces. These task forces based their decision on recommendations from a study by Ferrebee et al. (2014) that found that if an RCC pavement has similar design properties to conventional concrete, the design thicknesses could be the same, rather than inflating the design thickness of RCC relative to conventional JPCP which was the previous design guidance (Concrete Pavement Technology Center, 2010).

2.3 PavementDesigner's Continuously-Reinforced Concrete Pavement (CRCP) Design

PavementDesigner's methodology for Continuously-Reinforced Concrete Pavement (CRCP) follows the AASHTO 93 design procedure, but recommends that this only be used as an initial estimate, as CRCP should be designed with AASHTOWare's Pavement ME Design tool.

The "Project Level" inputs for the CRCP design module are the same as those in the JPCP and RCC modules. This means that the traffic estimation based on an existing asphalt design can be utilized for CRCP design as well.

The "Pavement Structure" includes all the same inputs from the JPCP "Pavement Structure," with additional inputs required to run an AASHTO 93 design, which include the adjustment factors for depth to rigid foundation and loss of support, load transfer coefficient, drainage coefficient, and initial and terminal serviceabilities. This can be seen in Figure 6.

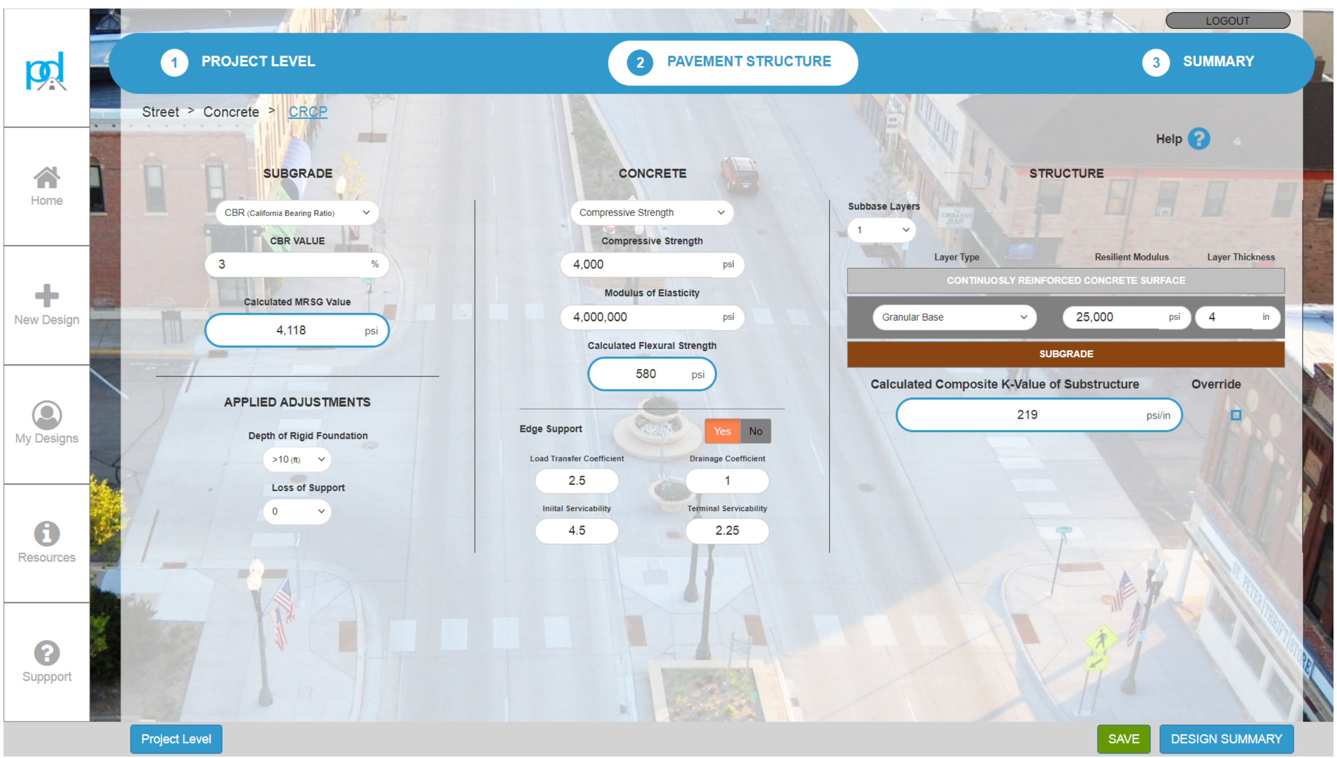


Figure – 6 PavementDesigner's "Pavement Structure" design screen for CRCP design

The "Summary" section for CRCP only includes the "Calculated Minimum Thickness" and the "Recommended Design Thickness" as CRCP does not have a sawed joint spacing and does not have a dowelled/undowelled scenario. Additionally, the CRCP "Summary" only includes four of the sensitivity plots featured in the JPCP and RCC modules, with the percent slabs cracked not being included.

An additional feature that is included in the CRCP design summary is a steel estimator that calculated the steel spacing, number of bars required per lane, and steel weight/lane-mile based on the design percentage steel required and the bar size to be used. This can be seen in Figure 7.

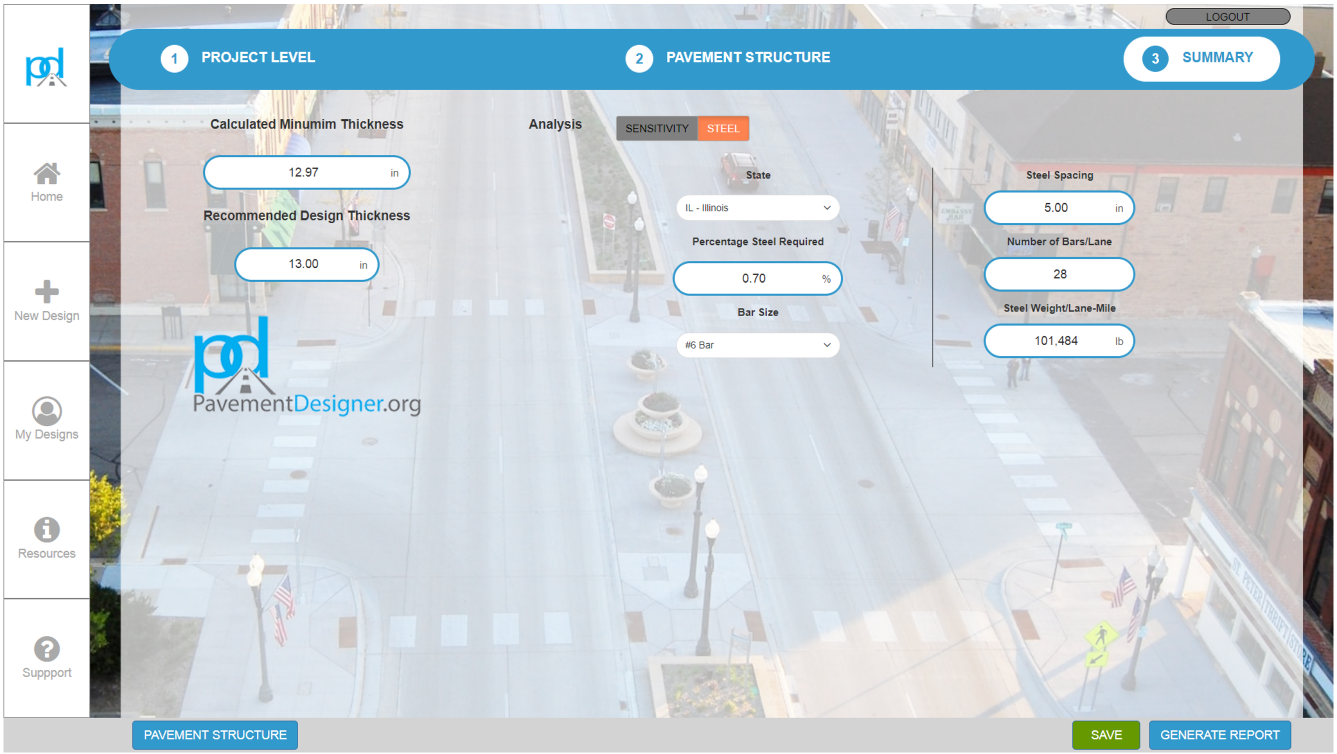


Figure 7. PavementDesigner's steel estimator for CRCP design

2.4 PavementDesigner's Overlay Design

PavementDesigner's overlay design allows for the design of bonded concrete overlays on existing concrete pavements (BCOC), and unbounded concrete overlays of concrete (UCOC) and asphalt (UCOA), and guides users to use design bonded concrete overlays of asphalt (BCOA) with the BCOA-ME design tool developed at the University of Pittsburgh (University of Pittsburgh, 2015). The design for the other three types of concrete overlay integrated the StreetPave 12 design methodology for overlays. The only alterations are the same as those featured in the JPCP module: the capability to estimate the traffic given an existing asphalt design, and an updated joint spacing calculation.

Given the similarities between the JPCP and Overlay modules, the "Project Level" pages remain consistent. The "Pavement Structure" parameters have been updated to include details on the existing surface that is being overlaid. The changes to the "Pavement Structure" inputs and calculated outputs for each type of overlay can be seen in Table 1, below.

Table 1 – New inputs and intermediate outputs within the Pavement Structure parameters for overlay designs relative to full-depth JPCP

Overlay Type	New Inputs	New Outputs
BCOC	• Existing concrete thickness • Unrepaired deteriorated joints, cracks and other • Fatigue adjustment factor • Durability adjustment factor	• Joints/cracks adjustment factor • Effective thickness of existing concrete
UCOC	• Existing concrete thickness • Unrepaired deteriorated joints, cracks and other	• Joints/cracks adjustment factor • Effective thickness of existing concrete
UCOA	• Existing asphalt resilient modulus • Existing asphalt thickness	• These are used in the calculation of the composite K-Value of the substructure

The new inputs and outputs are used to characterize the existing pavement, thus reducing the required overlay thickness relative to what would be calculated for a new full-depth JPCP section following the method set forth by the Army Corps of Engineers (1984). BCOC design calculates the required thickness for a new full-depth JPCP ($T_{required}$) and subtracts the effective thickness ($T_{effective}$) of the existing concrete to obtain the overlay thickness ($T_{overlay}$) as in equation 5, below:

$$T_{overlay} = T_{required} - T_{effective} = T_{required} - AF_{\frac{joint}{cracks}} * AF_{durability} * AF_{fatigue} * T_{existing} \quad (5)$$

where AF is an adjustment factor for the existing deteriorated joints and cracks, durability, and fatigue, and $T_{existing}$ is the existing concrete's thickness. A practical minimum of 2 inches is applied to the overlay thickness for constructability purposes. If the effective thickness is greater than the required thickness an overlay is not required and the thickness is reported as 0 inches.

UCOC design applies similar adjustments to obtain the effective thickness, but the calculation of the overlay thickness follow equation 6 below:

$$T_{overlay} = \sqrt{T_{required}{}^2 - T_{effective}{}^2} = \sqrt{T_{required}{}^2 - \left(AF_{\frac{joint}{cracks}} * T_{existing}\right)^2} \quad (6)$$

Similar to BCOC design, if the effective thickness is greater than the required thickness, it is assumed that an overlay is not required and the reported thickness is 0 inches. A practical minimum of 4 inches is applied for overlay thickness in UCOC.

In the UCOA case, the existing asphalt is simply applied as an existing layer in the substructure and is defined with the resilient modulus and asphalt thickness. The normal JPCP calculation is then utilized.

2.5 Pavement Designer's New Composite Design

PavementDesigner allows for the design of new composite pavements, or composites, that utilize a cement-altered layer within the subgrade or substructure to improve structural capacity. These pavements can utilize a JPCP, RCC, asphalt, or chip seal surface. The composite sections with a JPCP and RCC surface utilize the same design methodology as the JPCP and RCC designs described above and incorporate the cement-altered layer within the calculated composite k-value of the substructure. Composite pavements with an asphalt or chip seal surface are designed following the PCA-Pave design methodology which was developed based studies by PCA (1992) and Scullion et al. (2008). This section will review the designs for a new composite with an asphalt or chip seal surface.

The “Project Level” inputs are the same as those utilized in the JPCP design module except that reliability and percent slabs cracked are not included, as they are not required for the PCA-Pave design process. Additionally, the traffic cannot be estimated from an existing asphalt design. Since the PCA-Pave design methodology does not follow the AASHTO 93 method, the designs would not be comparable and would not provide a true equivalent section.

The “Pavement Structure” inputs require details on the surface layer (asphalt or chip seal), subgrade, and structure layers. The surface layer requires a poisson’s ratio and modulus of elasticity. The subgrade requires a thickness to rigid foundation, poisson’s ratio, and modulus of elasticity. Each structure layer (up to 4 are allowed) requires a modulus of elasticity, layer thickness, poisson’s ratio, and modulus or rupture. For all layers, the user defines an allowable damage.

Based on the models used within the PCA-Pave program, PavementDesigner calculates the damage in each of the structure layers as well as the subgrade rutting, and iterates the surface layer thickness such that the allowable damage is not exceeded within the design life. Since the structure layers and subgrade are not altered within the design process, the predicted damage may exceed the allowable damage defined by the user. In this case, the user needs to alter the structure layers to ensure they don’t fail underneath the surface layer that is designed.

3. PAVEMENTDESIGNER’S PARKING LOT DESIGN

As was previously discussed, the main design methodology for concrete parking lots is the ACI 330-08 Guide for the Design and Construction of Concrete Parking Lots, which was based on StreetPave runs. To allow users flexibility in their designs, PavementDesigner follows a slightly modified and simplified version of StreetPave.

The “Project Level” inputs define the traffic and global inputs by simply requiring a traffic spectrum, design life, trucks per day, reliability, and percent slabs cracked at the end of the design life. PavementDesigner assumes that the pavement is to be designed for all of these trucks and that they are not distributed in a direction or a lane as they are in the JPCP module. The “Pavement Structure” inputs are the same as those used in the JPCP module, but a table (shown in Figure 8, below) is introduced to help define the subgrade. The table presents three types of soils representing three levels of support (low, medium, and high). The user can select one of these soils directly in the table, or can define their own CBR value to characterize the subgrade, which is used in the composite K-Value of the substructure calculation as discussed in section 2.1.

The “Summary” displays the design match those of the JPCP design without dowel bars. The summary also includes five sensitivity plots showing the change in design thickness with changes in K-Value, flexural strength of the concrete, design life, reliability, and percent slabs cracked.

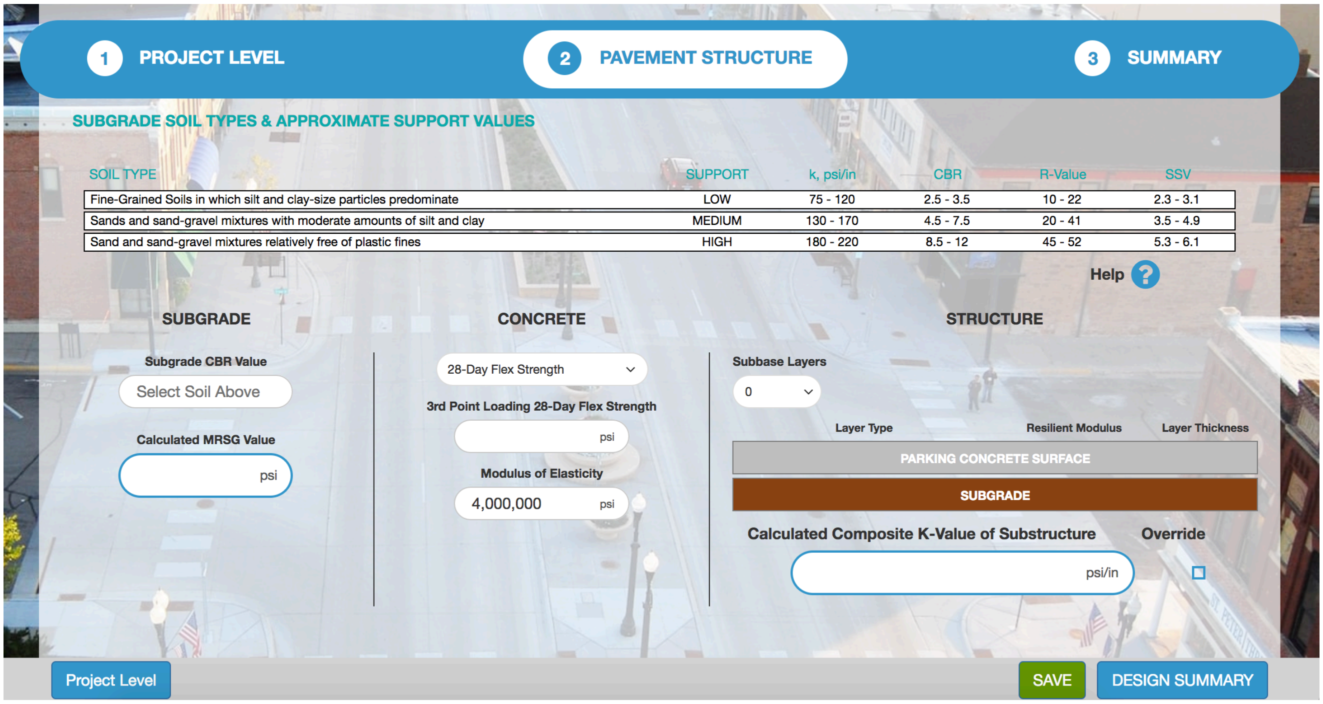


Figure 8 – Parking lot design’s pavement structure, including a soil type selection table

4. PAVEMENTDESIGNER’S INTERMODAL DESIGN

PavementDesigner features an intermodal design module for unique loading scenarios such as forklifts, agricultural equipment, and other off-road vehicles. This module is developed following ACPA’s AirPave design methodology (ACPA, 2011) which is based on a report by Packard (1973). This methodology was developed for pavement designs for aircraft and is thus suited to design for extremely heavy loadings with tires of varying tire pressure, as is often the case with off-road vehicles.

PavementDesigner’s intermodal design begins with the selection or definition of design vehicles. A library of default vehicles is included, but custom vehicles can be defined. Each vehicle is defined by wheel locations, a contact area for the tires, a contact pressure for the tires, and a gross weight of the vehicle that is distributed to all the tires. This is the only alteration from the AirPave design methodology, as it distributes 47.5% of the gross load to each of the two defined landing gear and assumes that 5% of the total load is on the nose gear.

Once the design vehicles are selected, the “Pavement Structure” inputs can be defined as they are in the JPCP module. PavementDesigner then iterates the thickness to reduce the calculated stress to a level where the stress ratio allows unlimited repetitions of all the design vehicles selected.

5. ADDITIONAL PAVEMENTDESIGNER FEATURES

PavementDesigner is intended to be a free, easy to use resource to designers. To make designing easy, users can create an account, save projects, and send projects to anyone. This allows designers to work together simply, without having to save anything to their local computer. Additionally, PavementDesigner has a “Resources” and “Support” section that can help users gain access to additional design guidance or details on a design methodology. It can also help them contact a design expert from the concrete pavement industry's network of local promoters to review the design methodology and provide input.

6. SUMMARY

PavementDesigner is a free, web-based pavement design tool for street and roads, parking lots, and intermodal facilities. The tool is the concrete pavement industry's recommended design tool for when AASHTOWare's Pavement ME Design program is not applicable.

PavementDesigner combines the industry recommended design approaches for JPCP, RCC, CRCP, overlays (BCOC, UCOC, BCOA, UCOA), new composite pavement, parking lots, and intermodal facilities into one tool, thereby eliminating some of the confusion over which design methodology should be used for a given facility. The simplified design procedure helps guide the user through the appropriate design methodology based on the designer's needs.

7. REFERENCES

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