ACPA

American Concrete Pavement Association

CONCRETE PAVEMENT PROGRESS

Volume 41, Number 5
May 18, 2005

This month ... Longevity and Durability of Pavements

Next month...

Design and construction of streets and local roads.

Understanding Life Cycle Cost Analysis

A review of the simple calculation

Life cycle cost analysis (LCCA) allows owners, agencies, and engineers to evaluate different alternatives for infrastructure projects. LCCA involves calculating the total costs to construct and maintain an asset such as a pavement over a designated time period.

In applying this concept to pavements, primary factors include: initial (first) costs; maintenance costs; rehabilitation costs; user costs; and reconstruction costs. Also, the different pavement alternatives should always be designed for the same amount of traffic and the same subgrade value, so that they are equivalent designs.

Present Worth and Equivalent Uniform Annual Cost

LCCA equates all present and future costs (and benefits) over the life of a project by accounting for the value of money over time. LCCA results can be presented in several ways. The two most common are present worth and equivalent uniform annual cost.

Present worth is the sum of all costs (and benefits) over the project life in today's dollars. It combines initial costs with discounted future maintenance costs, rehabilitation costs, and a salvage value. The future costs are discounted to account for the time value of money using the discount (real interest) rate. Present worth analysis is limited to comparing alternates with equal analysis periods.

Key factors to include in a life cycle cost analysis

There are two important categories of costs that should be considered in the evaluation of alternative pavement strategies - agency costs and user costs. These costs directly affect the pavement selection process.

Agency costs include:
* Initial construction costs
* Future construction or rehabilitation costs
* Maintenance costs recurring throughout the design period
* Salvage or residual value at the end of the design period (a negative cost)
* Engineering and administrative costs
* Traffic control costs

User costs include:
* Travel time
* Vehicle operation
* Accidents
* Discomfort
* Time delay and extra vehicle operating costs during resurfacing or major maintenance

Equivalent uniform annual cost spreads the cost of all items (initial, user, maintenance, and anticipated rehabilitation costs) annually over the analysis period. An analysis using equivalent uniform annual cost more effectively compares alternates with different service lives. However, when making such comparisons, the user must understand that the analysis is assuming that the same set of activities will be repeated indefinitely.

Simply a Calculation
The actual mechanics of performing a life cycle cost analysis are not complicated. It is a mathematical calculation of the anticipated expenditure flows over time. Though a computer program or spreadsheet is helpful in performing the calculations, an analyst does not necessarily need them.

Pavement Cost vs. Project Cost
In every pavement construction project, the actual cost of the pavement structure is only a portion of the total project cost. A recent sampling of construction projects shows that pavement costs average around 44% of the total project costs.

This is a small percentage when considering the intent of the construction project is to build or rehabilitate a given section of pavement. Since the complexity of a particular project can add significant costs, certain types of projects have lower pavement cost as a percentage of the total cost.

Concrete vs. Asphalt
The procedure does not favor one alternate over the other. There is no such thing as a concrete LCCA or an asphalt LCCA. The procedure cannot tell whether the calculated values are for a concrete pavement or an asphalt pavement.

The Basic Steps
There are six basic steps to performing a complete LCCA. They are:

1. Design equivalent pavement sections.
2. Develop expenditure streams for the analysis period: a. Determine the maintenance and rehabilitation strategies (activities and timing) to be used on the pavement over the analysis period; b. Estimate agency costs for each activity.
3. Estimate user costs.
4. Compute present worth or equivalent uniform annual cost.
5. Analyze results.
6. Reevaluate strategies, if needed.

Concrete Pavement Goes the Distance

By [Mike Ayers](), Ph.D.
Director of Highway Pavement Technology
American Concrete Pavement Association, Skokie, Ill.

Many factors are involved in deciding which pavement type to choose (concrete versus asphalt), as well as the design features to incorporate (doweled or undoweled, tied concrete shoulders or widened lane, stabilized or unstabilized base, etc.). The new Mechanistic-Empirical Design Guide and a thorough, fairly-applied life cycle cost analysis (LCCA) provide the means to make a good decision.

Pavement selection is increasingly challenging because of the relatively stable cost of portland cement concrete and the rising cost of asphalt. The differences in initial cost of the various pavement options are generally so minimal that the deciding factor relies on future maintenance costs.

LCCA has traditionally been used in making the crucial pavement selection decision. Future costs are based on the historic performance of pavements in a specific state or region, or on a national basis. Historical pavement performance is generally based on information in a state's pavement management system.

Engineering judgment may be necessary because the information does not always differentiate the design features for concrete pavements. For example, the performance of doweled pavements is likely to be very different than that of a non-doweled pavement under heavy traffic. A long-jointed, reinforced concrete pavement performs differently than a short-jointed plain pavement or a continuously reinforced concrete pavement.

A true comparison must consider "apples to apples" even though the majority of concrete pavements far exceed their design lives in terms of traffic carrying capacity and overall performance. The performance models used in predicting long-term pavement performance today are generally based on pavements designed and constructed up to 40 years ago.

Technological advances in restoration and rehabilitation methods, design, materials, equipment, and techniques that are in use today make concrete pavements better than ever.

Concrete pavements can be constructed in a relatively short time and can be designed virtually maintenance free for extended periods of time. In contrast, the best asphalt "perpetual pavement" requires the sacrificial surface to be removed and replaced on a routine basis, every few years.

This perpetual system also allows for adjustment to the underlying asphalt layer to account for structural inadequacy. The result of these actions is an asphalt pavement that, by design, mandates disruption to the traveling public, compromises public and worker safety in work zones, and results in ever-increasing user costs.

Pavement selection is increasingly challenging because of the relatively stable cost of portland cement concrete and the rising cost of asphalt.

Life cycle cost analysis is a very important tool in the pavement selection process. Realistic models are necessary in computing these costs. Realistic models are based on the performance of pavements with similar design features, environment, and traffic.

The new Mechanistic-Empirical Design Guide has great promise in facilitating a comparison of pavement options following local or regional calibration. When equivalent designs are compared and the cost to own and maintain pavements for an extended period are considered, concrete pavement is the obvious choice.

Making Concrete Durable - Part 4

By Jim Shilstone, Sr.
Chairman, The Shilstone Companies, Inc.

Editor's Note: *This is the final installment of a four-part editorial on concrete mix designs. This installment covers air entrainment -- when and how much?*

Unnecessary specification of high air contents in paving concrete is among the most costly requirements, because 28-day compressive strengths are typically reduced 5 to 10% for each percent over about 3%. Given today's prices for cement, the direct cost may be over $2.00 per cu. yd. Additional problems can be project delays or rejection of otherwise acceptable concrete. Research is now proving that the new generation of air entraining agents are very different. The latest products can produce smaller bubble sizes making it a difficult to identify using standard pressure testing.

As pointed out in Part 1, entrained air in concrete was first recognized in Kansas in 1933. The New York Highway Department in 1938 reported that their normal concrete mixtures resisted the effects of freezing and thawing. However, when snow and ice removal chemicals were applied, 3% air was needed to resist the effect of those chemicals. In both cases, the creation of the entrained air was caused by the material used as grinding aids used during grinding of the cement clinker. The mixtures cast during that period were based upon the use of well-graded combined aggregate following the guidelines reported in Lewis Institute Bulletins and publicized in the PCA's, 2nd edition of "Design and Control of Concrete Mixtures."

Wacker Drive in Chicago was replaced in 2002 after serving 75 years. It was not air entrained though snow and ice removal chemicals had been liberally applied. Concrete placed in New York harbor in 1922 still survives with no steel corrosion and no air entrainment. The Oakland Bay Bridge constructed in 1933-34 was not air entrained and there have been no problems associated with deterioration due to sulfates and the tidal zone.

During the 1950s - and especially the 1960s - the durability of concrete mixtures declined as they deviated widely from the characteristics of these cited Chicago, New York, and California mixtures. Primarily, concrete quality was based upon strength, durability problems were not recognized until years later. The prevailing over-sanded mixes required high air content for freeze/thaw protection.

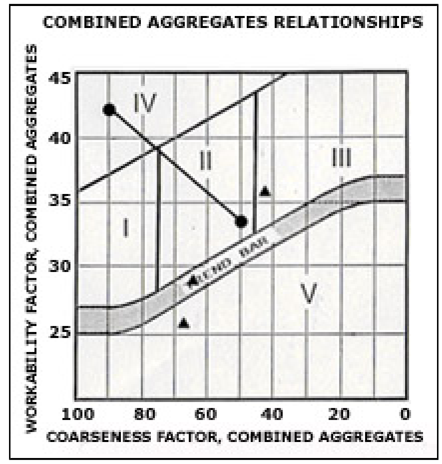
In 1959, the PCA issued Research Bulletin 40 recommended that the air content should be 9% of the mortar. That recommendation was reviewed by ACI Committee 211 and, apparently, someone judiciously extended that to mixtures by varying recommendation with the nominal maximum aggregate sizes and projected water contents. Those requirements are now standards in ACI 318. Based upon the high water provisions in ACI 211, it was apparently found that the air contents should be higher than necessary.

Modern technology is contributing to the return of well graded combined aggregate mixtures in accordance with the procedures recommended by the Lewis Institute and the PCA. The Coarseness Factor Chart (see Part 3), and shown below, is gaining recognition through ACPA and ACI, as well as specifications from state highway agencies and the U.S. Air Force. Mixtures in Zone I have been found to segregate. Zone II and III mixtures produce dense concrete. Mixtures in Zone IV are typical of many of the over-sanded concrete mixtures still in use in many areas.

We have examined Bulletin 40 and analyzed the mixtures. The coordinates for the typical Bulletin 40 mixes are shown as solid triangles on the Coarseness Factor Chart.

Based upon our experience, the coarser mixtures are not rational for today's construction. The one above the Trend Bar in Zone III may be questionable. So, we must ask the question, "When do we need to entrain air and how much is necessary?"

Recent research is yielding information that the air-entraining agent is a key to the size of air bubbles. Larger bubbles are created by the air entraining agents that have been used for many years (resin based). The smaller bubbles are created by the modern air entraining agents. Some are so small that they cannot be detected by pressure meters. Unit weight measurements may assist in determining the presence of entrained air. This result should be augmented by additional research recommended below.



The coordinates for the typical Bulletin 40 mixes are shown as solid triangles on this chart.

Recommended Research

Research is needed to develop guidelines for concrete mixtures based upon the grading on the combined aggregate.This will provide a comparison of mixtures similar to those cast before the 1950s and the over-sanded mixtures often cast today. The researchers should study mixtures along a line of points anchored by a CF = 50 with a W-Adj = 33.5 and a CF = 90 with a W-Adj =42.5. These points are approximately identified as dots on the above chart. There should be 3 to 5 intermediate research points along that line. Three mixtures should be tested for each research point. Each mixture should start with 560 pounds per cu. yd. of cement. No admixtures or air entraining agents should be used in the first series.

For each research point, determine the water requirement for the base non-air-entrained mixture. The second round should contain 3% entrained air and the third round should have 6% entrained air. Compressive strength specimens should be cast and the samples prepared for freeze/thaw testing. Conduct freeze/thaw tests for acceptance based upon ASTM C666.

Anticipated Results

Based upon the early data and field experience, it is anticipated that two curves will be developed. The first will reflect water demand based upon aggregate grading and the second will reflect the our hypothesis that well-graded, combined aggregate mixtures do not need more than 3% air. The PCA's second edition of "Design and Control of Concrete Mixtures" included the recommendation that mixtures be cast with 6.0 gallons of water per sack of cement to produce 3,000 psi strength to be adequate for the most stringent freezing and thawing problems in the northern United States.

The combined curves will demonstrate the financial and durability benefits of well graded combined aggregate mixtures as recommended by Prof. Duff Abrams in Bulletin 1, Lewis Institute, published in 1918. The bulletin provided the foundation for the old concrete that is often out-performing new concrete.

About the Author - Representing three generations of service to the transportation industry, Jim Shilstone, Sr., is Chairman of the Shilstone Companies, Dallas, TX. For more than 60 years, Shilstone has conducted extensive research on concrete mixture development and analysis. The research results led to standard changes for several institutions, including the American Society for Testing and Materials; the American Concrete Institute; and the U.S. Air Force.

Shilstone was recently recognized by the American Concrete Pavement Association, which awarded him its distinguished Honorary Life Membership, an award reserved exclusively for those who have rendered outstanding service to the concrete pavement industry and to the Association. Contact the author at The Shilstone Companies, 9400 N. Central Expy., #105, Dallas, TX, 75231. Phone: 214-361-9681. Fax: 214-361-7925.

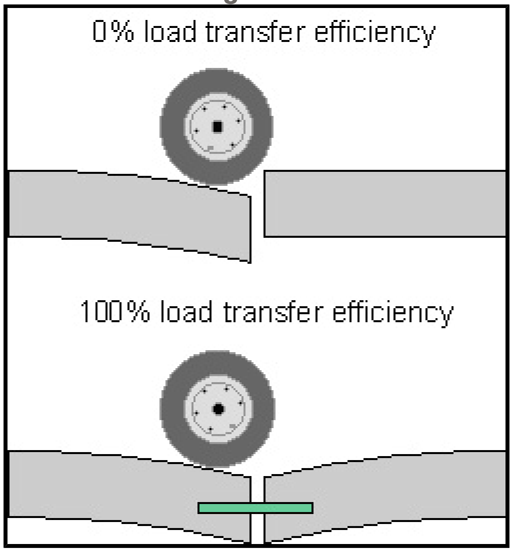
Does Load Transfer Affect the Longevity of a Pavement?

Load transfer can directly affect the longevity of a pavement. It is an important factor in the pavement's performance.

Most load transfer performance problems are disappearing from the performance records of modern concrete pavement because of the proliferation of doweled pavement designs. Joint distresses such as faulting, pumping, and corner breaks occur because of joints with poor load transfer efficiency. All of these problems worsen when joints deflect greatly under loads, but bars strengthen joints and may eliminate these problems.

Each type of joint provides a different ability to transfer load across slabs. This ability is termed load transfer effectiveness. It is determined as shown in Figure 1. Note that both sides of the joint deflect evenly at 100% load transfer efficiency.

Figure 1

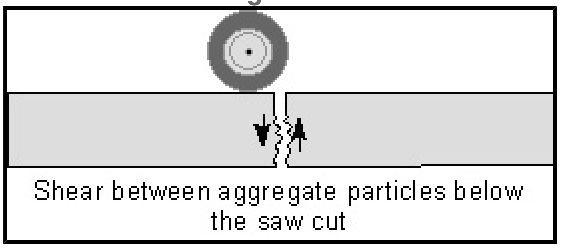


Dowel bars offer excellent load transfer by providing a mechanical connection between slabs without restricting horizontal joint movement. They also keep slabs in horizontal and vertical alignment. When loaded by heavy vehicles, dowel bars lower joint deflection and stress in the concrete slab and reduce the potential for joint problems by increasing load transfer efficiency.

For roadway pavements, the use of dowel bars in transverse contraction joints primarily depends upon the road or street classification and can also be determined by slab thickness. Because local roads typically do not require very thick slabs, doweled contraction joints are not usually used. However, they are used in industrial roads, major streets, highways, and airports that will carry heavy vehicles for long periods.

When dowels are not used, joints depend solely upon aggregate interlock for load transfer (see Figure 2). Aggregate interlock is the mechanical locking which forms between the fractured surfaces along the crack below the joint saw cut. Reliance on aggregate interlock without dowels is acceptable on low-volume and secondary road systems where truck traffic is low and slabs are typically less than 7 inches thick, but not for pavements that carry larger amounts of truck traffic.

Figure 2



Deformed steel tiebars are used in longitudinal joints primarily to prevent lanes from separating. By holding slabs tightly together, they enhance aggregate interlock and consequently load transfer.

For more information about load transfer, see *Design & Construction of Joints for Concrete Highways* (TB010P); *Design & Construction of Joints for Concrete Streets* (IS061P); or *Airfield Joints, Jointing Arrangements and Steel* (TB017P). To order ACPA publications, visit www.pavement.com; call toll-free 1-800-868-6733; or fax requests to 847-966-9666.

Southeast Improving Long Term Performance of Highway Ramps

The Tennessee DOT and the Southeast Chapter - ACPA improved the typical section of one-lane entrances and exit ramps on controlled access highways.

The new section has one cross slope from outside shoulder to outside shoulder. The improvement makes the ramp safer by eliminating differing cross slopes on the shoulders. The simple change has also made the ramp much easier and quicker to construct. The method allows the concrete ramp to be placed with one pass of the paving machine, instead of making three separate passes.

Tennessee's typical section for a one-lane ramp is a 4-ft paved inside shoulder, 16-ft wide travel lane, and a 6-ft paved outside shoulder. The method will improve long term performance of the ramp by eliminating the 16-ft slab width that was subject to longitudinal cracking along the center.

With the new construction, the longitudinal joint is sawed 12 ft from one edge, and 14 ft off the other edge. The striping centers the new joint right in the middle of the travel lane. Maintenance is also reduced by having one longitudinal joint to maintain instead of two. For more information, contact Jim Norris at 615-904-2269.

The concrete pavement work on SR-840, Williamson County, Tenn., was done by Interstate Concrete Constructors, LLC.

A Look Back

The world's first concrete runway

The world's first concrete runway was built in 1927 in Dearborn, Mich., by the Ford Motor Company for a Ford-manufactured plane called the Silver Goose.

With mass production of Tri-Motor Ford airplanes completed, the Fords set out on a massive, national ad campaign touting the safety of flight.

To make it seem even safer, they built a concrete runway at Ford Airport (now called the Ford Motor Co. Dearborn Proving Ground).

Photo depicts the airport as it appears today. The original runway was about 600 ft long.

"Henry Ford's greatest contribution to aviation was in building the first airport in the world with concrete runways," the Smithsonian said in its 1991 book "Aviation Milestones."

This and other early runways used variable pavement thicknessess similar to those early highways: concrete 8 or 9 in. thick. Until World War II, engineers designed these concrete pavements based on the anticipated loads imposed by refueling trucks carrying the gasoline to airplanes, rather than the airplanes themselves. **(Sources: The Henry Ford Museum)**

Concrete Pavement News Digest

ACPA Unveils New Logo

ACPA's new logo reflects the Association's bold, and dynamic approach, while also symbolizing concrete pavements.

ACPA has designed and implemented a new logo to usher in the Association's new direction and future initiatives.

The new logo reflects ACPA's bold, dynamic approach, while also symbolizing concrete pavements. Creation of the new logo is especially well-timed, given ACPA's new products to be released this summer; recent staff additions; and relocation of the Washington, D.C.-office. (Effective May 11, the office will be located at 1130 Connecticut Avenue, NW, Suite 1250, Washington, DC 20036. Phone: 202-887-8290. Fax: 202-887-8298.

Recycled Aggregates Filling a Needed Role

The American Association of State Highway Transportation Official's (AASHTO) task force on recycled materials is intending to allow contractors to tap into the tipping fee savings and the large volumes of material that can be theirs when they use recycled aggregates, said Cecil Jones, a materials engineer for the North Carolina DOT and chairman of task force on recycled materials.

The task force will work with the Recycled Materials Research Center at the University of New Hampshire to ensure testing and scrutiny of any new specifications. He also remarked that the environmental stewardship angle is important to him and other task force members. "It's the right thing to do," Jones said of concrete and asphalt recycling.

Jones told attendees he sees the task force's work as vital, since it will "help extend the limited [aggregate] resources that exist." Jones also noted, "It's very difficult to open a new quarry . . . even to expand is difficult." (Source: Recycling Today, an online newsletter.)

FHWA's Paul Teng Retires

Teng retires from FHWA.

ACPA extends its warmest wishes and hearty congratulations to T. Paul Teng, P.E, Director of the Federal Highway Administration's (FHWA) Office of Infrastructure Research & Development. After 24 years of Federal service, Teng retired on May 2.

In this key role at the FHWA's Turner-Fairbank Highway Research Center, McLean, Va., he directed a multi-level staff responsible for the improvement of highway infrastructure-related technology through research, development, and testing. He also led outreach efforts to identify future targets of opportunity and managed a range of advanced research initiatives.

Teng joined the FHWA in 1981 as Federal Program Manager for the Office of Research. He also served as Chief of the Pavement Division (Office of Engineering), as well as a number of other key positions in the agency. Prior to joining the FHWA, he held a range of engineering positions with the Mississippi State Highway Department.

On the occasion of Teng's retirement, Jerry Voigt, P.E., ACPA President and CEO, recalled, "Although we could scarcely describe your many accomplishments and contributions to our industry, we recall very clearly how, beginning in 1997, you helped reshape and refine the concrete pavement industry's research and technology transfer efforts through your participation as a blue-ribbon panelist on our 'Concrete Pavement Research Blueprint' initiative." Click here to read a letter written by Voigt that was sent to Teng.

Still Time to Register for International Conference

There is still time to register for the 8th International Conference on Concrete Pavements in Colorado Springs, Colo.The event, sponsored by the International Society for Concrete Pavements (ISCP), will be held August 13 - 18, in Colorado Springs, Colo. Click here for a brochure, which includes everything you need to know about the conference. For more information, contact Jason Weiss, Purdue University, at iscp8@ecn.purdue.edu.

Study Says Traffic Troubles Getting Worse

Traffic congestion in the United States is growing worse and getting more expensive, according to the 2005 Urban Mobility Report.

The report, published by the Texas Transportation Institute (TTI), also says that traffic congestion cost Americans $63.1 billion a year.

The report shows that the current pace of transportation improvement is not sufficient to keep pace with even a slow growth in travel demands in most major urban areas.
The problem? "Urban areas are not adding enough capacity, improving operations, or managing demand well enough to keep congestion from growing large," the report states.

Congestion occurs during longer portions of the day and delays more travelers and goods than ever before. The TTI study ranks areas according to several measurements, including:
*Annual delay per peak period (rush hour) traveler, which has grown from 16 hours to 47 hours since 1982,
*Number of urban areas with more than 20 hours of annual delay per peak traveler, which

has grown from only 5 in 1982 to 51 in 2003,

*Total amount of delay, reaching 3.7 billion hours in 2003, and .
*Wasted fuel, totaling 2.3 billion gallons lost to engines idling in traffic jams.

The report measures traffic congestion trends from 1982 to 2003, reflecting the most recent data available.
Click here to view the report.

TXI Announces Expansion in California

Texas Industries Inc. said it will expand and upgrade its portland cement plant in Oro Grande, Calif. The two-year job will increase plant capacity by 75 percent, adding 2.3 million tons of new capacity.

When the expansion is completed, 1.3 million tons of current production will be retired. The work will increase Texas Industries' total cement capacity to about 6 million tons, or by about 20 percent. (Source: **EXECUTIVE REPORT**, April 25, 2005, published by the Portland Cement Association.)

Uretek Publishes Infrastructure White Paper

Uretek USA released its second in an ongoing series of issues-oriented technical white papers addressing the challenges faced when dealing with subsurface infrastructure problems.

The paper covers the traditional methods of handling these problems, the URETEK approach, advantages and solutions followed with two exemplary case studies. It is downloadable from Uretek's website, as well as the names and locations of nationwide representatives for more information on specific infrastructure issues. To download the paper, visit www.uretekusa.com.

Research Board Announces Tire Efficiency Study

The Transportation Research Board's (TRB) Committee on National Tire Efficiency started an initiative to study how pavements influence tire efficiency.

The committee's study will:

- Consider the relationship that the rolling resistance of replacement tires (for cars and trucks) has on fuel consumption and tire wear life;
- Address the potential for securing technically feasible and cost-effective replacement tires that do not adversely affect safety. This will include the impacts on performance and durability, the impact of tire tread life, and scrap tire disposal;
- Consider the average American "drive cycles";
- Address the cost to the consumer, including the additional cost of replacement tires and any potential fuel savings.

The study is being sponsored by the U.S. Department of Transportation's National Highway Traffic Safety Administration. It is expected to be completed by early 2006. For more information, visit the TRB website, www.trb.org.

Degussa Names National Pavement Sales Manager

Degussa Admixtures, Inc., recently named Don Brogna as National Paving Manager. He will be responsible for the coordination and implementation of the Degussa Admixtures leadership role in the highway and airport paving market.

Brogna, a 32-year veteran at Degussa, will be on national strategic accounts, training, and participation in relevant trade associations. He sits on the American Concrete Institute's 325 Concrete Pavement Committee and 308 Concrete Curing.

Degussa Admixtures, Inc. markets the Master Builders brand of chemical admixtures and silica fume used in the production of specialty and high quality concrete.

ACPA Concrete Pavement Progress is published 12 times per year and covers current practices and case histories in the concrete pavement industry. ACPA **Concrete Pavement Progress** is distributed free of charge to public officials, ACPA members, executive committee, board of directors, and affiliated chapter/state paving associations.

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