Slag Cement and Life Cycle Prediction Models

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Life cycle prediction models are engineering tools used to predict the life and establish the cost of a structure including maintenance and repair.

What are Life Cycle Prediction Models?

Life cycle prediction models are engineering tools developed from an understanding of concrete performance, gained from basic material research and engineering practice and used to predict the life and establish the cost of a structure, including maintenance and repair. This cost is a balance between the initial fixed cost of construction labor and materials and the variable cost of extended maintenance and repair (subject to the time value of money). Poor initial choices in material selection or construction practices can lead to long-term maintenance and repair expenses that exceed the cost of construction.

Life Cycle Cost of Concrete Construction

Some of the properties that may increase the useful life of a concrete structure and decrease life cycle cost are:

- Low permeability
- Increased corrosion resistance
- High compressive and flexure strength
- Improved resistance to sulfate attack
- Better resistance to alkali silica reactivity (ASR)
- Reduced thermal stress

Other important factors that can impact a concrete structure's life cycle include a structures relationship to the physical environment; structural design and detailing; mixture proportioning and admixtures; reinforcement; concrete production, placement and curing; and construction methods.

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Slag Cement, Life Cycle Prediction and Cost

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Chemically, slag cement improves resistance to aggressive sulfate solutions and mitigates deleterious reactions between cement alkalis and reactive silica in aggregates.

Physically, slag cement reduces the heat of hydration, thus lessening thermal cracking and improves ultimate compressive and flexural strength. During the life of the structure, these strengths normally increase well beyond the 28-day specified strength, significantly more than plain portland cement concrete.

Possibly the most important effect provided by the use of slag cement is decreased concrete permeability. Lowered permeability inhibits the ingress of chloride ions that can contribute to corrosion of reinforcing steel. Additionally, keeping water out of the concrete matrix significantly decreases susceptibility to many durability problems, such as sulfate attack and ASR.

Slag Cement and Life Cycle Prediction Models

A life cycle cost computer model (ACI Life 365)[1], developed in cooperation with the American Concrete Institute's Strategic Development Council, can be used to evaluate the beneficial effect slag cement has on structural durability. It predicts the time to corrosion onset, time for corrosion to reach an unacceptable level, determines a repair schedule after first repair and finally estimates a life-cycle cost based on the initial concrete cost and future repair costs. An example output from this program is shown in Figure 1.

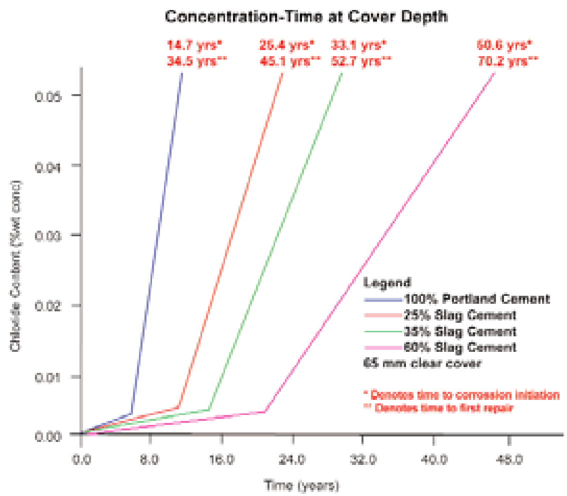

Figure 1: Typical output from ACI Life 365 Service Life Prediction Model demonstrates the significant improvements possible in time to initial corrosion and first repair when slag cement is used. Assumptions include: Urban bridge deck in Minneapolis, 65 mm clear cover and use of epoxy coated reinforcing steel. (Red text denotes annotations to Life 365 output).

In a real-world example, the Maryland State Highway Administration constructed a bridge deck for Route 64 in Smithburg, MD (Figure 2) and compared standard concrete with high performance concrete (HPC).[3] Corrosion on the deck would initiate at 13 years. Adding epoxy-coated reinforcing steel inhibits corrosion for an additional 25 years. Use of HPC that incorporated 40 percent slag cement, a corrosion-inhibiting admixture and fibers (to limit cracking), increased time to first corrosion to 50 years, and time to significant repair to 75 years. The HPC bridge deck added only $15,000 to the cost of the structure but increased bridge life by an estimated 37 years. The ACI Maryland Chapter recognized this project with an award for excellence in concrete construction.

Figure 2: Route 64 bridge deck in Smithsburg, MD used high performance concrete with 40 percent slag cement as part of a corrosion-resistant system that extended the predicted life of the structure by 37 years. (Contractor-Joseph Faye Co.; Concrete Supplier-Thomas Bennett Hunter)

While all methods of providing durability should be considered when designing a structure, slag cement can be an efficient and cost effective alternative to more expensive solutions, and can easily be incorporated in an overall strategy to provide a concrete structure that minimizes life cycle costs.

As with all concrete mixtures, trial batches should be performed to verify concrete properties. Results may vary due to a variety of circumstances, including temperature and mixture components, among other things. You should consult your slag cement professional for assistance. Nothing contained herein shall be considered or construed as a warranty or guarantee, either expressed or implied, including any warranty of fitness for a particular purpose.

References
1. Bentz, E., and Thomas, M., Life 365 Service Life Prediction Model (Version 1.1.0), Silica Fume Association, Cleveland, Ohio, 2001.
2. Violetta, B., "Life 365 Service Life Prediction Model," pp 53-57, Concrete International, Farmington Hills, Michigan, December 2000.
3. ACI 365.1R-00 Service-Life Prediction-State-of-the-Art Report, American Concrete Institute, Farmington Hills, Michigan, 2000.

The use of 40 percent slag cement played a significant role in increasing the estimated service life of a Maryland bridge deck from 38 years to 75 years.

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About the Slag Cement Association...

The Slag Cement Association is the leading source of knowledge on blast-furnace slag-based cementitious products. We promote the increased use and acceptance of these products by coordinating the resources of member companies. We educate customers, specifiers and other end-users on the varied attributes, benefits and uses of these products.