History of Type K Shrinkage Compensating Cement

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Discovery

Alexander Klein
- University of California, Berkeley
- Late 1950s
- Invents ASTM Type K Cement
  - Based on Klein Compound
  - $\text{C}_4\text{A}_3\text{S}$

Cements Controlled Expansion: Ettringite

Ettringite Crystals

Nucleation of Ettringite Crystals

Nucleation of Ettringite (Bescher Balls)
Chemical Pre-stressing

- First use of Klein's compound
- **Mechanism**
  - As the concrete expands chemically
  - The steel rebar elongates and is stressed in tension
  - Creating compression in the concrete
- Can achieve 500 psi compression in the concrete after drying shrinkage losses
- Volume of work could not support commercial production

Shrinkage Compensating Concrete

- First use was to address problems in post-tensioned structures due to drying shrinkage
- Mixing Klein's expansive compound with Portland Cement meant drying shrinkage could be eliminated
- With this additional market, the need for Klein's compound was sufficient to warrant protection in a full-scale cement plant

ACI 223: Figure 2.5.3

- ASTM specifications were developed to help test and define the material
  - ASTM C878 Standard Test Method for Restrained Expansion of Shrinkage Compensating Concrete
  - Modification of C157 — added 0.15% rebar restraint to match minimum reinforcing steel required in 1960s
  - Often called “Rubin Bars” for Ed Rubin, FACI
Defining the Material

ASTM C845 defines expansion at 7 days

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<tr>
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<th>0.04%</th>
<th>0.1%</th>
<th>0.2%</th>
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<tbody>
<tr>
<td>Shrinkage Compensating Concrete</td>
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<td>Chemical Prestressed Concrete</td>
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<td>Expansion at 28 days not to exceed 0.15%</td>
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Why were these limits chosen?

- For Shrinkage Compensated Concrete (0.04%-0.1%)
  - Ability to substitute Type K Shrinkage Compensating Cement for any concrete structure without changing the reinforcing or joint detail
- For Chemical Pre-Stressed Concrete (> 0.2%)
  - To create a clear difference between Shrinkage Compensated and Chemical Pre-stressed concrete

Manufacturing

- Patents for Klein's compound were applied for in 1963
- First full-scale manufacture to use x-ray diffraction was Kaiser Cement Company
  - Get an order and we will make it vs. make some and we will sell it
- Caltrans places an order for 2 miles of highway in 1963
  - These two sections are still performing well
  - In a 2003 review, they rank in the top 10% of Caltrans pavement performance

Early Research

- ACI Klein Symposium 1972
- ACI Cedric Wilson Symposium 1977

Improvements

- From 1963 until the 1980s, Type K Cement was made by inter grinding an expansive clinker and Portland Cement clinker
- Grinding the clinkers separately had many advantages
  1. Control of particle size – better slump control
  2. Freight – hauling only 15% of product
  3. Produce a range of expansions
- Improvements continue to be made to the cement
  - XRD used to control the chemistry in the kiln, with readings in the plant every 30 minutes
- In general, today's cement is uniform in properties
- Many improvements of Type K Cement have been made in the last 10 years
Caltrans: One Mile of Type K Pavement in 1963

Folded Plate Roof Type K in 1963

Workers finish peaked roof sections of savings and loan building in Yuba City, CA. Expansive cement was used for this structure, which has no expansion or contraction joints and no other surfacing on top of concrete.

A house that is all Type K Concrete. All roofs are monolithic concrete without roofing. The entire structure has only one joint.

Industrial building with roof parking using Type K in 1963

Post-tensioned Type-K cement concrete provides superior durability for Chicago’s O’Hare Airport. 9,000 car parking structure constructed in 1973.
Uses: History of Type K Cement

Rockford Airport: The finished 1,200 foot post-tensioned taxiway without joints in 1993.

Type-K in post-tensioned floor members in TRW buildings in 1968. Structural condition of the floor system and columns is virtually crack-free after 40 years.

Toyota Warehouse in Ontario, CA, 1995
760,000 sq. ft. Type K Concrete.

Southport Waste Water Treatment Plant expansion in Indianapolis, IN, 1984.

Questions