




American Concrete Institute®  
Advancing concrete knowledge

## Shrinkage-Compensating Concrete—Past, Present, and Future, Part 1

ACI Fall 2012 Convention  
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ACI  
WEB SESSIONS




**Edward K. Rice** holds B.S. and M.S. degrees in Civil Engineering from the University of California, Berkeley and taught Civil Engineering at UCLA. He co-founded T.Y. Lin and Associates and served as President from 1952 - 1970. He founded CTS Cement Company in 1975, and is currently Chairman of the Board. He is a Fellow of the American Society of Civil Engineers and the American Concrete Institute; Voting Member, ASTM C1 and C9. He sits on both the UC Berkeley and the UCLA Engineering Advisory Boards. He is the UC Berkeley Distinguished Engineering Alumnus (1987) and was elected to the Post-Tensioning Institute Hall Of Fame (2005). He received the UCLA Engineering Service Award (2002) for 50 years of service. He is a registered engineer and a licensed contractor in California and holds 20 U.S. patents in the field of cement and concrete technology.

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### History of Type K Shrinkage Compensating Cement

Edward K. Rice, PE, FACI, FASCE



### Discovery



**Alexander Klein**

- University of California, Berkeley
- Late 1950s
- Invents ASTM Type K Cement
  - Based on Klein Compound
  - $C_4A_3S$

1902-1970




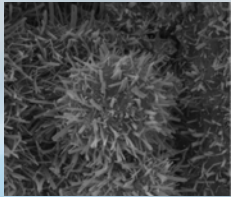
### Cements Controlled Expansion: Ettringite




Ettringite Crystals



### Nucleation of Ettringite Crystals

Nucleation of Ettringite (Bescher Balls)




## Chemical Pre-stressing

CTS CEMENT KSC


- 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

## Chemical Pre-stressing

CTS CEMENT KSC



Testing a chemically pre-stressed slab



Testing a chemically pre-stressed pipe

## Chemical Pre-stressing

CTS CEMENT KSC






6 story precast apartment building in 1968

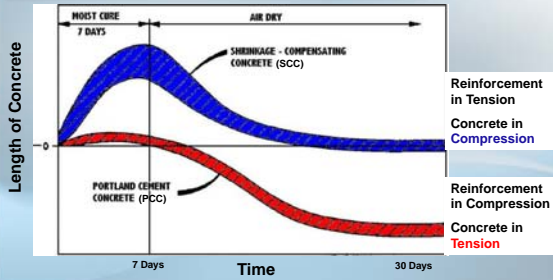
## Shrinkage Compensating Concrete

CTS CEMENT KSC

- 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

CTS CEMENT KSC



Length of Concrete

Time

MOIST CURE 7 DAYS

AIR DRY

SHRINKAGE - COMPENSATING CONCRETE (SCC)

PORTLAND CEMENT CONCRETE (PCC)

7 Days

30 Days

Reinforcement in Tension

Concrete in Compression

Reinforcement in Compression

Concrete in Tension

ACI 223 Standard Practice for the use of Shrinkage Compensating Concrete

## Defining the Material

CTS CEMENT KSC

- 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
  - ASTM C806 Standard Test Method for Restrained Expansion of Expansive Cement Mortar
  - ASTM C845 Standard Specification for Expansive Hydraulic Cement

## Defining the Material

ASTM C845 defines expansion at 7 days

0.04%      0.1%      0.2%

Shrinkage Compensating Concrete

Chemical Prestressed Concrete

Expansion at 28 days not to exceed 0.15%

## Defining the Material

- 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
  - Control of particle size – better slump control
  - Freight – hauling only 15% of product
  - Produce a range of expansions

## Improvements

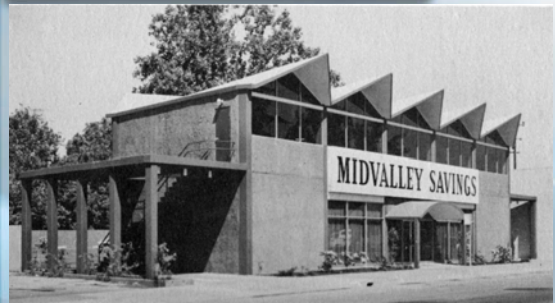
- Improvements continue to be made to the cement
- XRD used to control the chemistry in the kiln, with readings in the plant every 30 minutes
- In general, today's cement is uniform in properties
- Many improvements of Type K Cement have been made in the last 10 years

Uses: History of Type K Cement



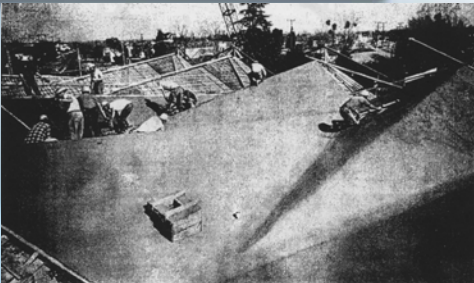
Caltrans: One Mile of Type K Pavement in 1963

Uses: History of Type K Cement



Folded Plate Roof Type K in 1963

Uses: History of Type K Cement



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.

Uses: History of Type K Cement



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

Uses: History of Type K Cement






Industrial building with roof parking using Type K in 1963

Uses: History of Type K Cement






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

**Uses: History of Type K Cement**  



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.

**Uses: History of Type K Cement**  



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

**Uses: History of Type K Cement**  



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

**Questions**  

