

4) Geopolymer Concrete

Why did it take so long ?

4) Geopolymer Cement

WHY DID IT TAKE 30 YEARS ?

from the invention in 1983-1984

until the successful commercialization in Australia,

100,000 tonnes geopolymer concrete for Airport in 2014

U.S.A.

Lone Star Industries

Geopolymer cement, PYRAMENT

(1983, 11 years after begin of research, 1972)



Barry University, Miami, Florida

Institute for Applied Archaeological Sciences

1st PYRAMENT patent

United States Patent [1]

Davidovits et al.

[11] Patent Number: 4,509,985

[45] Date of Patent: Apr. 9, 1985

[54] EARLY HIGH-STRENGTH MINERAL POLYMER

[75] Inventors: Joseph Davidovits, Saint-Quentin, France; James L. Sawyer, Friendswood, Tex.

[73] Assignee: Pyrament Inc., Houston, Tex.

[21] Appl. No.: 582,279

[22] Filed: Feb. 22, 1984 **1984**

[51] Int. Cl.³ C04B 19/04

[52] U.S. Cl. 106/84; 106/85; 106/117

[58] Field of Search 106/84, 85, 117

[56] References Cited

U.S. PATENT DOCUMENTS

4,349,386 9/1982 Davidovits 106/85

Primary Examiner—James Poer
Attorney, Agent, or Firm—McAulay, Fields, Fisher, Goldstein & Nissen

[57] ABSTRACT

An early high-strength mineral polymer composition is formed of a polysialatesiloxo material obtained by adding a reactant mixture consisting of alumino-silicate oxide ($\text{Si}_2\text{O}_5, \text{Al}_2\text{O}_2$) with the aluminum cation in a four-fold coordination, strong alkalis such as sodium hydroxide and/or potassium hydroxide, water, and a sodium/potassium polysilicate solution; and from 15 to 26 parts, by weight, based upon the reactive mixture of the polysialatesiloxo polymer of ground blast furnace slag. Sufficient hardening for demolding is obtained in about 1 hour with this composition.

6 Claims, No Drawings

Lone Star/PYRAMENT cement



Los Angeles: a crew begins placing geopolymer concrete.
New York: a Boeing departs

1 hour
Strong enough to walk on

4 hours
Strong enough to drive on

6 hours
Ready for the weight of a commercial jet

Start March **1983** / all rights sold to Lone Star Ind. Oct. **1989**
PYRAMENT PBC until 1997

Why so long ?

- 1) Every alkali-activated waste = Geopolymer !!!
- 2) RILEM : AAM alkali-activated-materials
- 3) For civil engineers: alkali = danger
- 4) The standards

Why so long ?

- 1) Every alkali-activated waste
=
Geopolymer !!!



1- Fly Ash from SGC

2- NaOH solution

3- Sand

4- Crushed stone dust

5- Na_2SiO_3 solution

alkali-activated fly ash concrete wrongly called “geopolymer”



WHY ? Because we must follow geopolymerization mechanism

1. Alkalinization
2. Depolymerization of silicates
3. Gel formation of oligo-sialates
4. Polycondensation
5. Reticulation, networking
6. Geopolymer solidification

Why so long ?

2) RILEM committee AAM

Alkali-Activated Materials

State-of-the-Art Report, RILEM TC 224-AAM

1. Introduction and Scope

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Version

1.4 Notes on terminology

engine. In the context of this Report, the terms 'alkali-activated material (AAM)' and 'geopolymer' are at least worthy of some comment:

- Alkali activated material (AAM) is the broadest classification, encompassing essentially any binder system derived by the reaction of an alkali metal source

- Geopolymers [17] are in many instances viewed as a subset of AAMs, where the binding phase is almost exclusively aluminosilicate and highly coordinated [18,

The distinction between these classifications is shown schematically in Figure 1-2. This is obviously a highly simplified view of the chemistry of concrete-forming systems; any

Geopolymers are shown here as a subset of AAMs, with the highest Al and lowest Ca concentrations.

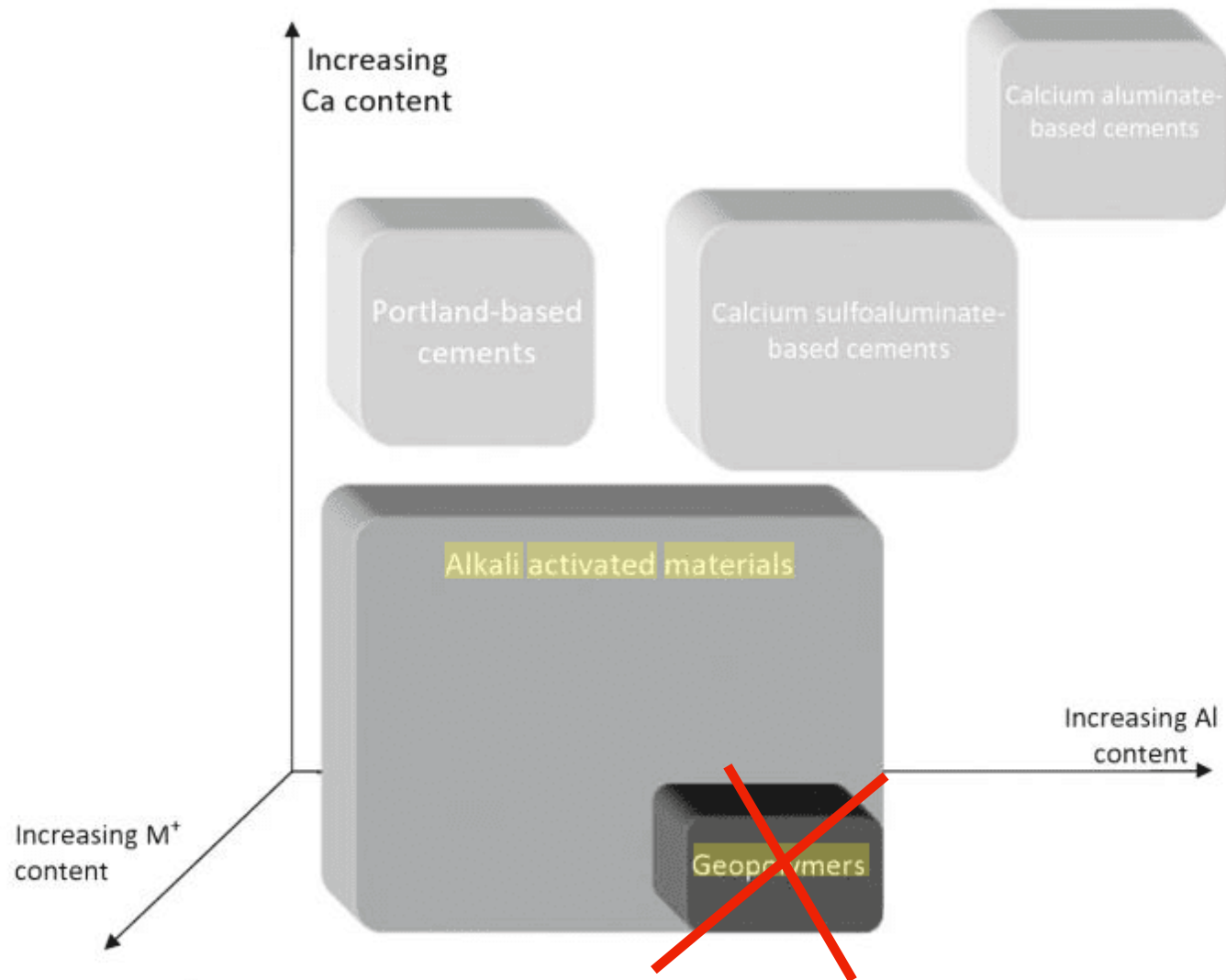


Fig. 1.2 Classification of AAMs, with comparisons to OPC and calcium sulfoaluminate binder chemistry. *Shading* indicates approximate **alkali** content; *darker shading* corresponds to higher concentrations of Na and/or K (Diagram courtesy of I. Beleña)

“ I am a PhD student in civil engineering interested in producing geopolymers from several by-products.

But in your publications, you state that geopolymer is not an alkali-activated product, whereas other publications are claiming that there is no difference between the two, I got confused.”

Geopolymers

high molecular, macromolecules, polymers

Alkali-activated Materials AAM with NASH / KASH
are hydrates, not POLYMERS.

They cannot be called GEO-POLYMERS

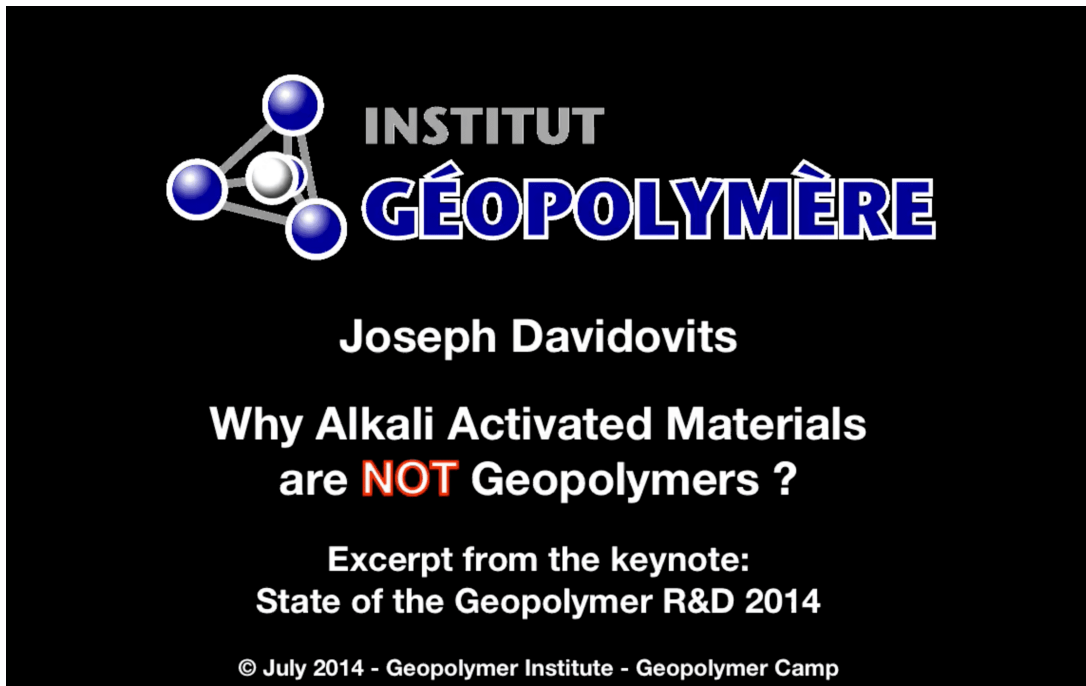
2 very different systems!

It is a big scientific mistake to use both as synonyms.

Alkali-activation is a wrong terminology for geopolymers.



Why Alkali-Activated Materials (AAM) are not Geopolymers ?



statistics as of April 2018

Part 1: Aug. 2014

Excerpt Geopolymer R&D 2014

GP-Institute > 16000 YouTube > 7300

Part 2: Aug. 2015

Excerpt Geopolymer R&D 2015

Part 2: Clarifying statement and historicity.

GP-Institute > 7000 YouTube > 2400

Part 3: Aug. 2016

Excerpt Geopolymer R&D 2016

Part 3: What scientists are now writing on this issue

GP-Institute > 4000 YouTube > 1100

Part 4: Aug. 2017

Excerpt Geopolymer R&D 2016

Part 4: NASH / KASH is an invalid terminology

GP-Institute > 1600 YouTube > 450

Why so long ?

3) For civil engineers: alkali = danger

AAR

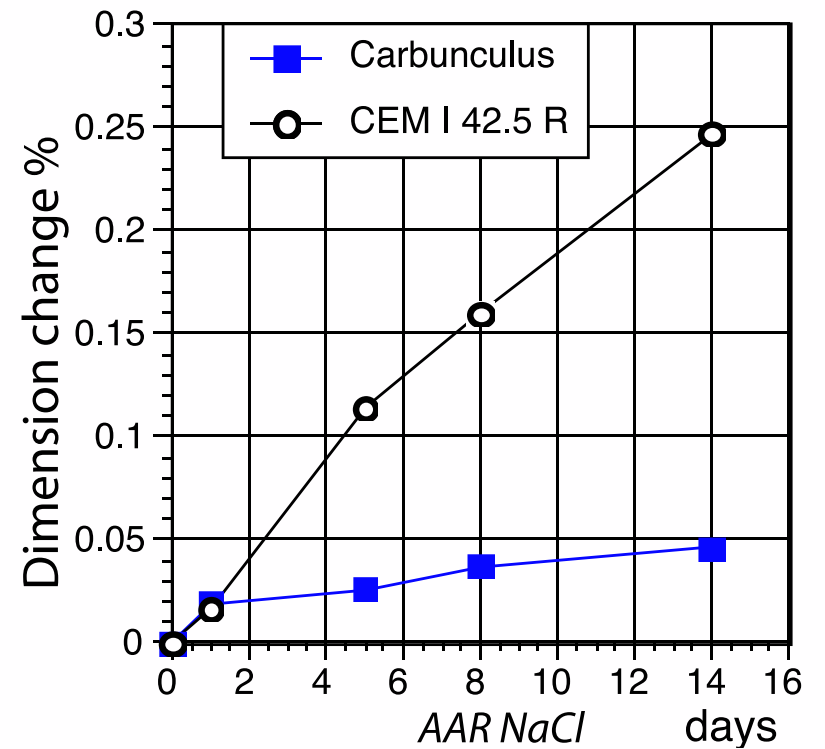
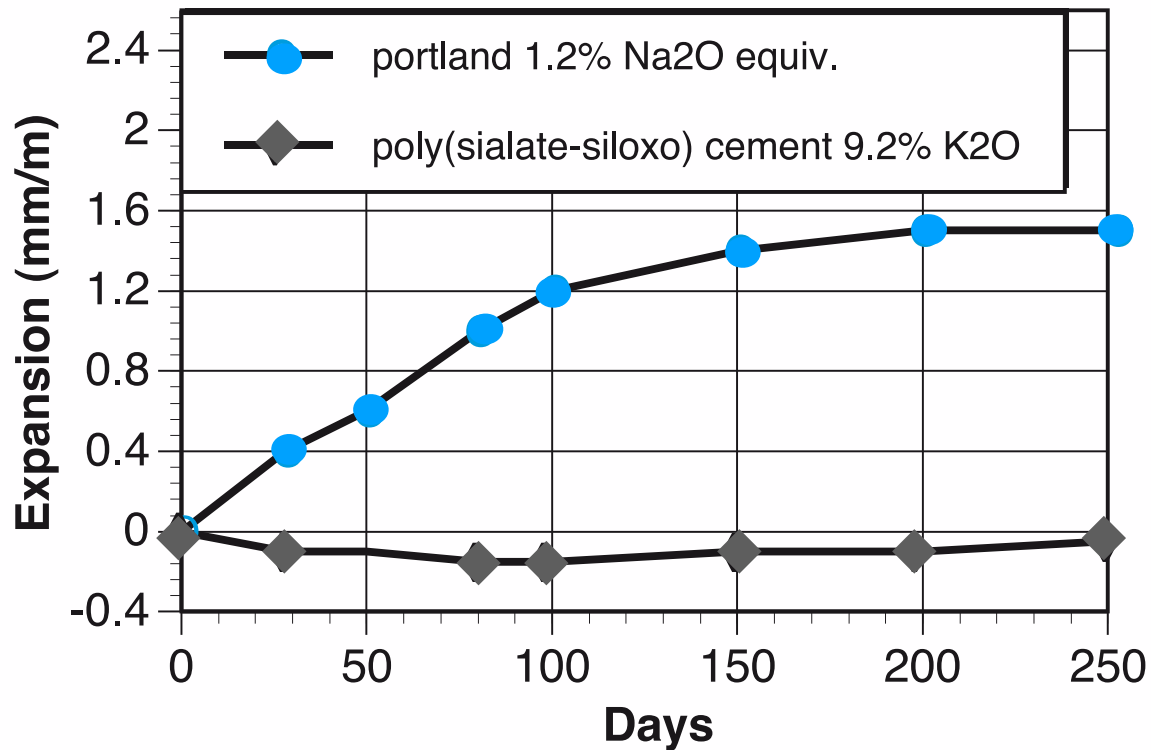
alkali-aggregate reaction

ASR

alkali-silica-reaction

As early as 1993 in ACI (USA) publication

A.A.R. on Portland and Geopolymer



Why so long ?

4) The standards



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Technical paper #21 Geopolymer LIBRARY

GEOPOLYMER CEMENT

a review

by

Professor Joseph Davidovits

January 2013

The existing Portland cement standards are not adapted to geopolimer cements. They must be created by an *ad hoc* committee. Yet, to do so, requires also the presence of standard geopolimer cements.

Presently, every expert is providing his own recipe based on local raw materials (wastes, by-products or extracted).

There is a need for selecting the right geopolimer cement category.

The 2012 State of the Geopolymer R&D, suggested to select two categories, namely:

- *Slag/fly ash-based geopolymer cement*: fly ashes are available in the major emerging countries;
- *Rock-based / MK-geopolymer cement*: this raw material is present in all countries through out the globe.

European concrete standard EN 206 has a restriction that potential binders should comply with *European cement standard* EN 197 which contains Portland cement clinker, and therefore technically excludes geopolymers.

Australian Standard for Concrete Structures (AS 3600) does not specify Portland cement based concrete. The components of the Standard are primarily *performance based*.

In USA, recent adoption of **ASTM C1157**, *Performance Specification for Hydraulic Cement* (the first version of ASTM C1157 appeared in 2000), represents an important development in this area.

ASTM C1157 simply requires that the cement meet physical performance test requirements.

The use of ASTM C1157 is being implemented on a small number of projects to evaluate its effectiveness. The Colorado DOT (Department of Transportation) has been a leader in the use of performance-specified cements and has used them on a number of highway projects.

Last words

Today, very few cement applications with fly-ash, mine tailings or other wastes.

Because of standards, regulations...

Today's applications are Niche-Market but with **high-value added**.

The solution: don't sell a material...

Sell a **solution** that people are **willing to pay for**.