Applications for Non-traditional Cements in Highway Transportation Systems

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Applications for Non-traditional Cements in Highway Transportation Systems

- Different types of non-traditional cements
- Different types of applications for these non-traditional cements
- Survey of states
- Standards and Test Methods
- Obstacles to using these non-traditional cements

Applications for Non-traditional Cements in Highway Transportation Systems

- What this presentation is not?
  - ✓ This presentation does not cover chemical admixtures requiring the use of Portland Cements
  - ✓ This presentation does not cover mineral admixtures (such as Fly Ash, GGBF Slab, Silica Fume, Metakaolin, Rice Hull Ash, etc) requiring the use of Portland Cements for activity
  - ✓ This presentation does not cover Portland Cements blended with or added to any of the following materials
- Does not necessarily cover all Non-Portland Cements

Belite Based Cements

- Belite cement produced from fly ash
- Is formed mainly by the alpha prime of low temperature dicalcium silicate (L-Ca_2SiO_4), and containing elements such as Fe, Al, Mg, Na and K that increased the reactivity of L-Ca_2SiO_4.
- Advantages:
  - ✓ Reduction of the temperature of the synthesis (800 °C vs 1450 °C)
  - ✓ Reduction of the needs for the grinding process
  - ✓ CO_2 emission reduction during the furnace process
  - ✓ Waste from an industrial process is used as raw material

Belite Based Cements

- Disadvantages:
  - ✓ Needs to be cured in temperatures of 40 ºC
  - ✓ Requires water reducing admixtures
  - ✓ Primarily made in the laboratory and might not be economically feasible in large production
- Applications:
  - ✓ None if it is only made in the laboratory

Calcium Sulfoaluminate Based Binders

- Calcium sulfoaluminate cements include ye'elimite ($Ca_4(AlO_2)_6SO_4$) as a primary phase
- Hydration produces mainly ettringite
- lower limestone content and lower fuel consumption leads to a CO_2 emission around half that associated with Portland clinker.
- SO_2 emissions are usually higher.
- Advantages:
  - ✓ High early strengths
  - ✓ Rapid setting time
  - ✓ Tiny expansion and low shrinkage
  - ✓ Low Alkali
  - ✓ Durability

Calcium Sulfoaluminate Based Binders

- Disadvantages:
  - ✓ Not recommended for mixing with other types of cements
  - ✓ Might lead to corrosion of reinforcing steel due to low alkali
- Applications:
  - ✓ It can be used for preparing anti-permeability, anti-freezing and sulfate resistance concrete.
  - ✓ used in construction in winter, injecting slurry, consolidation, rush to repair, leak stopping, complex geology small caliber running cementing, big prefabricated concrete structure, cast-in-place frame structure projects.
  - ✓ It is specially used for producing glass fiber cement composite products, cement pipe, cement pole and man-made marble products.
  - ✓ In engineering can cause multiples increase to output and economic value.
  - ✓ Super-high-strength It is fit to making concrete with performances of early strength, high strength (Above C60), impermeability, sulfate resistance.
  - ✓ It is also used in construction at negative temperatures, segmental contactor, block, large building engineering and it is used in mining support as well as laneway support.

Calcium Aluminate Cement

- CACs are made primarily from limestone and bauxite.
- Active ingredients are monocalcium aluminate ($CaAl_2O_4$) and Mayenite ($Ca_{12}Al_{14}O_{33}$)
- Advantages:
  - ✓ Rapid strength development is achieved, even at low temperatures
  - ✓ High chemical resistance is possible
  - ✓ Strength is maintained at high temperatures
  - ✓ As a component in blended cement formulations, various properties such as ultra-rapid strength development and controlled expansion can be obtained.

Calcium Aluminate Cement

- Disadvantages:
  - ✓ Structural fractures due to high early strengths
  - ✓ Very high cost
- Applications:
  - ✓ They are well-adapted for use in refractory (high-temperature resistant) concretes, e.g. for furnace linings.

Geopolymer Cement Composites

- Generally formed by reaction of an aluminosilicate powder
- Metakaolin is a commonly used starting material for laboratory synthesis of geopolymers
- Generated by thermal activation of kaolinite clay
- Can also be made from natural sources of pozzolanic materials, such as fly ash from coal.

Geopolymer Cement Composites

- Advantages
  - ✓ Very high early strength
  - ✓ Cures at ambient temperatures
  - ✓ Fire resistant to high temperatures
  - ✓ Reduction of CO_2 emmissions

Geopolymer Cement Composites

- Disadvantages:
  - ✓ Not typically being marketed
  - ✓ Needs chemical agents that might be dangerous
- Applications:
  - ✓ ideal material for repairing runways made of concrete, industrial pavements, and highway roads
  - ✓ In the case of a runway, a 4-6 hours hardening is enough to allow the landing of an Airbus or a Boeing
  - ✓ The geopolymeric cement reaches a compression strength of 20 Mpa after 4 hours
  - ✓ plainin concrete gets to this strength after several days.

Phosphate Cements Binders

- Advantages:
  - ✓ Very quick setting, high early strength
  - ✓ Recycling lot of non-contaminated industrial waste to building material
  - ✓ Recycling organic waste to building materials
  - ✓ Stabilization of toxic and radioactive waste
  - ✓ Very good durability, including chemical attack resistance, deicer scaling resistance, permeation resistance.

Phosphate Cements Binders

- Disadvantages:
  - ✓ Tends to break down in water and particularly in acids
  - ✓ Corrosion of steel reinforcing also occurs
- Applications:
  - ✓ Due to its rapid setting and high early strength, magnesium phosphate cement (MPC) has been utilized in raped repair of concrete structure, such as highway, airport runway, and bridge decks for many years
  - ✓ Due to its the lower alkalinity of MPC matrices (pH value 10 to 11) makes them potentially better suited to vegetable fiber reinforcement

Miscellaneous Inorganic Binders

- Pozzolan-lime cements
  - ✓ Mixtures of ground pozzolan and lime are the cements used by the Romans
  - ✓ E.g. the Pantheon
  - ✓ Develop strength slowly, but their ultimate strength can be very high
  - ✓ The hydration products that produce strength are essentially the same as those produced by Portland cement
- Slag-lime cements are similar to pozzolan lime cements
  - ✓ Ground granulated blast furnace slag
    - is not hydraulic on its own,
  - ✓ “activated” by addition of alkalis, most economically using lime

Miscellaneous Inorganic Binders

- "Natural" Cements correspond to certain cements of the pre-Portland era,
  - ✓ produced by burning argillaceous limestones at moderate temperatures.
  - ✓ The level of clay components (around 30-35%) is such that large amounts of belite (the low-early strength, high-late strength mineral in Portland cement)
  - ✓ Most of these inorganic binders are not readily available due to economic reasons

Survey of the State DOT's

- The following questions were sent to all of the different State Department of Transportations and Ministries of Transportation in Canada:

  1. Does your agency currently allow the use of any non-Portland Cement materials for use on DOT Projects as a binder or repair material? Non-Portland Cements could be magnesium activated cements, low-lime cements, alkali activated cements or sulfate activated cements.
  2. If so, what are the typical applications?

Survey of the State DOT's

- The following questions were sent to all of the different State Department of Transportations and Ministries of Transportation in Canada:

  3. Has there been any research performed by your Department on any type of non-Portland Cement Materials?

  4. If there was a national specification developed for the use of non-Portland cements, would you be willing to use this specification on a DOT project?

Survey of the State DOT's

Organization Name	1	2	3	4	Comments
Alabama	No	N/A	No	Possibly	That depends on a lot of variables as yet not quantified
California	Yes	Repairs	Yes	Possibly	Typical applications are patching spalls in deteriorated bridge decks.
Colorado	Yes	Repairs	No	Yes	We use ASTM C 928 for concrete patching materials
Connecticut	No	N/A	No	Yes	
Florida	Yes	Repairs	Yes	Yes	We allow the use of use non Portland cement based materials primarily for repair of bridge decks and structural concrete members. We allow the use of MAPC for the repair of high-stress areas segmental bridges. We've recently completed a research program which was used to update the FDOT Standard Specification regarding repair materials
Idaho	Yes	Repairs	Yes	No	
Illinois	No	N/A	No	Yes	
Iowa	No	N/A	No	Possibly	

Survey of the State DOT's

Organization Name	1	2	3	4	Comments
Kansas	Yes	Dowel Bar retrofit	No	Yes	NTPEP is developing a specification for repair materials
Louisiana	No	N/A	No	No	
Maine	No	N/A	No	Possibly	We would need more information / research before allowing it on a project
Massachusetts	No	N/A	No	Possibly	
Michigan	Yes	Yes	Yes	Possibly	Bridge deck repair, Very limited research
Minnesota	No	N/A	No	Possibly	We would need to see research on the subject
Missouri	No	N/A	No	Possibly	
New Hampshire	No	N/A	No	Yes	

Survey of the State DOT's

Organization Name	1	2	3	4	Comments
New York	Yes	Concrete Repair / PCC pavement repair	Yes	No	#3 NTPEP 2002 #5 - NYS has an expensive materials testing program which evaluates products for their suitability on Department project applications. Since our specifications are performance based - if a given material meets the minimum requirements of the specification (regardless of the type of cement it consists of) it can be determined acceptable for use
North Carolina	No	N/A	No	Yes	
Ohio	No	N/A	No	No	Although they answered no on the survey, Florida and Ohio have shared information regarding the use of non-Portland cement based repair materials used in both states.
Ontario MTO	Yes	Repairs	Yes	Yes	Some testing was performed on ciment fondu (high aluminum cement)
Rhode Island	No	N/A	No	Possibly	
South Dakota	Yes	Repairs	No	Unknown	Materials that meet ASTM C 928 can be used on patching of bridges with PCC pavements
Texas	Yes	Repairs	Yes	Yes	The typical use is for bridge deck repairs and armor joint repair

Survey of the State DOT's

Organization Name	1	2	3	4	Comments
Utah	No	N/A	No	Possibly	
Washington	No	N/A	No	Yes	
West Virginia	Yes	Repairs	No	Yes	Repair around modular expansion joints
Wisconsin	Yes	Repairs	No	Possibly	Repair of Bridge Decks

Survey of the State DOT's

- 26 States and 1 ministry of transportation responded to the survey
- Summary of results from responding agencies

Question Number	Answered "Yes"	Answered "No"	No response
1	15	12	0
3	7	20	0
4	22	4	1

Survey of the State DOT's

- Question #1 - Of the 15 respondents that responded "yes" question #1, all of them listed repair applications as their use.
  - ✓ The uses were primarily bridge deck repair and rapid patching applications
- Question #2 - "If so, what are the typical applications?"
  - ✓ was not designed to provide a "yes or no" answer, but to provide a typical use for the non-traditional cements the DOT's are currently using Non-traditional cements for

Survey of the State DOT's

- Question #4 "If there was a national specification developed for the use of non-Portland cements, would you be willing to use this specification on a DOT project?"
  - ✓ 11 of the responses were returned with "possible" response.
  - ✓ For the purposes of this survey, possible responses are considered to be a "yes" answer
  - ✓ relevant agency is considering the use of a non-traditional cements in their state

Standards and Test Methods

- ASTM C 928-05 – Packaged, Dry, Rapid-Hardening Cementitious Materials for Concrete Repairs
  - ✓ Only for repairing of concrete
  - ✓ Allows any type of cement with tests for performance
- ASTM C 1600-08 – Rapid Hardening Hydraulic Cement
  - ✓ Performance based standard
  - ✓ Allow any type of cement, as long as it is rapid hardening
- ASTM C 1157-08 – Hydraulic Cement
  - ✓ Performance based standard

Obstacles to using these non-traditional cements

- Availability
- General Acceptance
- Proven results based on standardized procedures
- Cost

Everyone has to understand that no one can repair everything…

Any questions?

Thank you!!!