Development and Application of Cementitious Composites in Thailand
Authors

- **Naveed Anwar, D. Eng.**
  - Associate Director ACECOMS, Affiliated Faculty Structural Eng, Director Habitech, Asian Institute of Technology, Thailand

- **Pichai Nimityongskul, D. Eng.**
  - Associate Professor (Structural Eng.), Director (IFIC), Asian Institute of Technology, Thailand

- **Lilia Robles Austriaco, D. Eng.**
  - Dean (Civil Eng.), College of Engineering, Angeles University, Angeles City, Philippines
  - Former Director (IFIC), AIT
Composites are engineering materials made from two or more constituent materials to form one component.

Cementitious Composites are unique man-made materials which are different from conventional construction materials such as steel, concrete, wood, and aluminium.

Two main constituents:
- a structural constituent, such as fibres, particles, laminae or layers, flakes, and fillers
- body constituent or matrix, which acts as a binder, stabilizer and load distributor, encloses the composite, and gives it its bulk form.
Advantages

- Corrosion-resistant, low life-cycle cost
- Lightweight materials, economical transportation, easier handling, and faster erection using relatively light equipment
- Wide range of applications in industries i.e. shower stalls and bath tubs made of fiber glass, imitation granite and cultured marble sinks and countertops etc.
- Savings in labour costs
Contents

- Introduction
- Developments in Thailand
  - Primary Cementitious Composites
  - Supplementary Cementitious Material
- Conclusions
Developments in Thailand

- Ferrocement
- Vetiver Grass
- Bamboo Reinforced Conc.
- Glassfiber Reinforced Conc.
- Fiber Reinforced Conc.
Ferrocement

Skeletal Steel

Wire Mesh

Mortar

Sand

Cement

Water

Woven Wire Mesh
Expanded metal Wire
Vinyl Wire Mesh
Welded Wire Mesh
Hexagonal Wire Mesh
Properties

- Tensile Strength
- Flexural Strength
- Toughness
- Durability
- Home made/ Easy Construction
- Fatigue Resistance
- Impact Resistance
- Cracking Resistance
- Cheap
- etc.
The International Ferrocement Information Center (IFIC)

- Founded in October 1976 at the Asian Institute of Technology under the joint sponsorship of the Institute's Structural Engineering and Construction Program and the Library and Regional Documentation Center (LRDC) and other international organizations.

IFIC objectives

- to collect, repackage and disseminate information of ferrocement and related materials; and
- to promote proper utilization of ferrocement
IFIC, AIT Thailand

Ferrocement Park
Applications in Thailand

- Housing
- Agricultural
- Water & Sanitation
- Marine
- Industrial

Ferrocement
Thai Traditional House
Degreed-Ellipse House (ACECOMS-ISI USA Project)
Floating House

Ferrocement
Intact Structures Inc., USA
Degreed-Ellipse House

Additional Beam
Extended Wall Rib

Top Roof
Roof
Wall

Ferrocement

Critical location of tensile stress in main ribs
Location of critical tensile force in Y-Y direction in big main ribs in pure shell structure (for load combination LC5)
Agriculture and Water

- Used in construction of grain storage bins to reduce losses from attack by birds, insects, rodents and molds.
- Thailo, a conical ferrocement bin; designed and first constructed at AIT, one to ten tons.
- ACECOMS and IFIC Designed, Constructed and Tested Water Reservoir for United Nations High Commissioner for Refugees (UNHCR) with capacities of 45,000, 75,000 and 90,000 litres.
- Ferrocement and bamboo-cement rainwater collection tanks are being built on a self-help basis by villagers under the supervision of an appropriate technology group to provide clean drinking water.
- Biogas digesters and holders, septic tanks, etc.
Agricultural

Water & Sanitation

Ferrocement
More than 30 ferrocement boats have been built with the size varying between 5-24m.
Other Applications

- **Blast Resistant Panels**
  - A joint research Royal Thai Air Force Academy and AIT
  - Panels of thickness 2.0 cm possess higher blast load resistance than 10-cm thick conventional plastered masonry walls
  - Latest experiment includes ferrocement bomb basket.

- Use of ferrocement as strengthening and retrofitting materials to withstand extreme heat or fire
  - Jacketed ferrocement enhances the fire resistance of composite elements
Applications of “Vetiver Grass”
(Crysopogon zizanioides)

- A Stiff grass 2-3 m grass, grows in the tropic and semi-tropic regions
  - China, Thailand, India, Vietnam, Ecuador, Italy, Indonesia, Latin America, Hawaii etc.
- Highly tolerant to:
  - extreme climatic variations such as drought, flood, prolonged submergence and extreme temperatures
  - wide range of soil acidity, alkalinity, sodicity and salinity
  - wide rage of toxicities including heavy metals in the soils.
- The roots of the grass have an average tensile strength of 75 Mpa and improves the shear strength of soil by between 30 and 40%.
Vetiver grass growing in floating pontoons

Sea dyke stabilization in Vietnam

Indian handicrafts from vetiver roots
For construction purposes, it takes 8 months - 1 year of growing period before cutting, and sun-dried.

The first systemic research approach spearheaded by Richard G. Grimshaw th Vetiver Network with newsletters in the late 1980’s and early 1990’s (Vitt, 2007)

World Bank Paper #273 was the earliest collection of these newsletters.

The Vetiver Network web-site is the definite guide to vetiver grass research, articles, and discussions (http://www.vetiver.org)
Production

Baling Techniques

“Bale” or giant bricks

Plastering

Nebraska Style Straw Bale Building

Vetiver Grass
Developments in AIT

- A research team from the School of Engineering and Technology (SET) used vetiver grass to replace cement for construction, together with locally available material as the bonding agent in producing vetiver grass sheet.
- The ash gives the concrete a unique property-increasing the concrete resistance against acidic attack.
- The research team has recently presented patent certificates on vetiver grass development technology to His Majesty King Bhumibol Adulyadej of Thailand.
  - Vetiver grass cement composites
  - Use of vetiver grass ash as a cement replacement
  - Process of producing vetiver grass ash
  - Construction of silo from vetiver grass and clay.
Silo Storage Bin

- **Foundation:**
  using steel reinf. bar (depending on the soil condition)

- **Ground Wall and Slab:**
  Using cement block filled with reinforced concrete

- **Silo Wall:**
  Using vetiver-clay bundle and coating with the mixture of cow dunk, clay and chopped vetiver

- **Roof:**
  Using 2-layer bamboo structure with dried-vetiver bundle

**Dimensions:**
- 3.0 meter dia.
- Height: 3.0 meter
- Elevated Floor: 1.20 meter (an outlet for taking the paddy out)
- Volume: 20 sq.m.
Housing Applications
Housing Application

- Research project on “Development of Prefabricated Vetiver-Clay Composite for Housing Applications” for constructing a low-cost house
- Research on the utilization of vetiver grass as construction materials for constructing prefabricated camps for refugees.
- Use of vetiver grass ash for engineering work, using vetiver grass sheet for interior design, and using it as a replacement of packaging foam.
Availability

In Thailand, bamboos concentrated in an area of more than 850,000 hectares located 130 km west of Bangkok, with total weight of over 7 millions air-dry ton, out of which 1.65 million tons grow in economically accessible area.

Road Construction

Bamboo reinforced concrete roads have received special attention. In 1989, the Public Works Department of Thailand started a program to construct bamboo reinforced concrete pavement village roads. Altogether 863 village road projects, with a total road length of over 500kms spreading all over the country.

Water Tanks

Bamboo reinforced concrete is also used for construction of water tanks. It is estimated that over 50,000 bamboo reinforced concrete water tanks have been built and the investment has been over 300 million baht (US $ 11.5 million).
Figure 14: Bamboo fibers prepared by manual hammering.

Figure 21: Pull-out test set-up.
Glassfiber reinforced concrete (GRFC) is a unique mixture of cement and sand reinforced with a special glassfiber, creating a thin but strong material which may be easily formed into a wide variety of ornamental shapes.

Many of Bangkok's most recognized building including the Wall Street Tower, Peninsular Plaza, Amarin Plaza and the New Grand Hyatt Erawan Hotel use glassfiber reinforced concrete (GRC).

Large glassfiber reinforced structures have been used extensively in the construction industry. For example, tub and showers units, patio covers, exterior building panels, and doors.
A research on the use of Thai silk as reinforcement in fiber-reinforced composites was carried out in SET, AIT. The objective of the research was to find the fiber that can be used for replacing certain non-renewable synthetic fibers such as glass with renewable natural fibers as reinforcement in polymer composites. The study result showed that the using the same fiber volume fraction, Thai silk fiber reinforced matrix cost 33 % less than glass fiber reinforced matrix.
Thai Silk Fiber Reinforced Matrix

Thai Silk

Epoxy resin

Put the Epoxy resin

Lay the silk

Lay over the epoxy

Hardening

Compressive Test

Load (kN)

Deflection (mm.)
Contents

- Introduction
- Developments in Thailand
  - Primary Cementitious Composites
  - Supplementary Cementitious Material
- Conclusions
Supplementary Cementitious Materials

- High Strength and Durable Concrete
- Replacement of Cement
  - Low W/C
  - Optimum Cement
  - High Strength Concrete
  - Efficient Mix Design
- Supplementary Cementitious Materials
  -Aggregate
  - Silica fumes
  - Superplasticizer
  - Cement
  - Fly Ash

Efficient Mix Design
Supplementary Cementitious Material

- The use of active or inactive micro-fillers such as silica fume, fly ash, metakaolin has significant effect on matrix, porosity, strength, and durability.
- There has been a lot research work carried out in the cementitious materials in Thailand.
- The most widely used cementitious material is Fly Ash from industrial waste.
  - Fly ash used is 90 %
  - Rice husk ash used is 8% and remaining is 2 %.
Fly Ash

- The amount of fly ash produced annually is approximately 3 million tons during the past 10 years.
- About 95% of the total production is obtained from the Mae Moh power generating plant operated by the Electricity Generating Authority of Thailand in Lampang province, in the north of Thailand.
Fly Ash

- Mae Moh fly ash contains a high percentage of calcium and is being used quite extensively for construction in Thailand.
- A lot of research work has been conducted as a part of master and doctoral thesis work at SET, AIT on the mix design of fly ash cement concrete:
  - For ready-mixed concrete = 20 to 30% by weight of the total cementitious materials.
  - For prestressed concrete industries = 10%.
  - For self-compacting concrete = 30% to 50%
Rice Husk Ash

- Thailand and other Asian countries produce a large amount of paddy.
- Rice husk, a by-product is used as a fuel in a boiler in the rice mills or the small electricity generating plant and for brick burning.
- Although increased use of rice husk is evident, much of the husk is disposed of by open field burning.
- The interest on making cement from rice husk is worldwide.
- Rice husk, when burnt contains a very high percentage of silica (SiO₂). With proper burning and grinding the amorphous reactive rice husk ash (RHA) produced is being used as pozzolans.
Other Agricultural Waste

- The Building Scientific Research Center (BSRC) has carried out research work on the use of natural fibres as an admixture on composite materials over four years ago.
- A new lightweight composite concrete and particleboards were developed using young coconut (Cocos nucifera), durian peel (Durio zibethinus) and coconut coir.
- The manufactured specimens have good thermo physical properties and have low thermal conductivity.
- On-going studies on the durability and long-term performance of these materials so that commercial development might start.
Conclusions

- It can be said that Thailand has been very successful regarding the usage of cementitious composites in construction industry.
- The use of laminated composites as ferrocement and cementitious material especially fly ash has become one of the significant factors to change the concept of design and construction practice considering both strength and durability.
- Innovative use of Bambo, Vetiver Grass, Thai Silk, Coconut Fibre is being investigated
- New ideas are being considered