COMPOSITE MATERIALS

Contents

- Ceramic Matrix Composites
- Geo synthetics
- Pre-stressed Hollow Concrete Panel
- Carbon Composites Fullerenes
- Bucky Ball Structures
- Graphene.

• Ceramic materials are in general brittle, and, according to the fracture mechanics, the strength is governed by the flaw size and the fracture toughness.

• General approaches for producing strong ceramics are to reduce the maximum size of processing flaws or to enhance the fracture toughness.

• The former approach, however, is limited by the nature of the microstructure of ceramics, since a grain boundary itself can be a flaw responsible for brittle fracture, and surface flaws generated in use may also reduce the strength of ceramics.

• Considerable effort has been made to develop toughened ceramics with high fracture toughness.

• The fracture toughness of ceramics is improved by introduction of secondary phases into matrix materials when the secondary phases are chosen to act as barriers to crack propagation.

• Whiskers introduced into a ceramic matrix, for example, can retard the crack propagation because the stresses in a whisker spanning the crack plane will tend to pull the crack shut. This phenomenon, known as "crack bridging", leads to higher fracture toughness due to the additional stress required for further propagation of the crack.

- Moreover, continuous fiber composites exhibit quasi-ductile
- fracture behavior resulting from extensive fiber bridging.

Ceramic matrix composites may be classified into two categories.

- One is a group of toughened ceramics reinforced with particulates and whiskers, and these materials exhibit brittle behavior in spite of considerable improvements in fracture toughness and strength. The maximum in fracture toughness is around 10 MPam^{1/2} or more.
- The second consists of **continuous-fiber composites** exhibiting quasi-ductile fracture behavior accompanied by extensive fiber pull out. The fracture toughness of this class of materials can be higher than 20 MPam^{1/2} when produced with weak interfaces between the fibers and matrix.

 $\,\circ\,$ The matrix is relatively hard and brittle

The reinforcement must have high tensile strength to arrest crack growth

 The reinforcement must be free to pull out as a crack extends, so the reinforcement- matrix bond must be relatively weak

	Comparative typical property guide for oxide matrices.								
Matrix	Crystal structure	Melting point in pure form, (°C)	Onset of reduction in reducing atmospheres, (°C)	Theoretical density, (Mg m ⁻³)	Elastic modulus, (GPa)	Typical flexural strength, (MPa)	Thermal expansion coefficient, 10 ⁻⁶ K ⁻¹ (25 1000°C)	Thermal conductivity, W m ⁻¹ K ⁻¹ (25 °C)	Electrical conduction ^c
Alumina, Al ₂ O ₃	Hexagonal	2060	1400	3.986	400	300	8	≈38	Insulator
Y TZP ^a	Tetragonal	2300	400 (darkens)	6.10	210	800	10	≈1.5	Insulator/oxygen ion conductor
PSZ ^b	Cubic/ tetragonal	2300	400 (darkens)	6.05	200	500	10	≈1.5	Insulator/oxygen ion conductor
Mullite, 3Al ₂ O ₃ .2SiO ₂	Orthorhombic	1934	1000 (darkens)	3.1	300	250	5	≈ 10	Insulator
Yttrium aluminum garnet (YAG)	Cubic	2000	1400		280	250	8	≈15	Insulator
Spinel, MgO.Al ₂ O ₃	Cubic	2135	1400	3.59	280	250	8	≈15	Insulator
Na beta alumina	Hexagonal			≈3.5	320	300	8		Sodium ion conductor

^a TZP tetragonal zirconia polycrystals, containing a high proportion of metastable tetragonal ZrO₂, see Section 4.01.5.5. ^b PSZ partially stabilized zirconia, with insufficient stabilizer to form an all-cubic phase material, see Section .5.5. ^c Given in general descriptive terms; actual values are usually strong functions of composition, phase distribution, and temperature. Most oxides are electronic insulators. Those indicated become ionically conducting at raised temperature, typically above 300 400 °C.

Oxide matrices and typical useful reinforcements.						
Matrix	Particulates	Platelets	Whiskers	<i>Fibers</i> SiC, Al ₂ O ₃ , 3Al ₂ O ₃ .2SiO ₂		
Alumina, Al ₂ O ₃	ZrO ₂ , SiC, TiC, TiN, TiB ₂ , ZrB ₂ , metals	SiC	SiC, B ₄ C			
Y TZP ^a	Al_2O_3	Al_2O_3	Al_2O_3	2 7 2		
PSZ ^b	$Al_2 O_3$	SiC				
Mullite,	Al_2O_3 , ZrO_2	Al_2O_3	SiC	SiC, Al ₂ O ₃		
3Al ₂ O ₃ .2SiO ₂						
Yttrium aluminum garnet (YAG)			Al_2O_3	Al_2O_3		
Spinel, MgO.Al ₂ O ₃	$Al_2 O_3$					
Na beta alumina	ZrO ₂					

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^b PSZ partially stabilized zirconia, with insufficient stabilizer to form an all-cubic phase material

- Types of ceramic-matrix composites
- AI_2O_3 -ZrO₂ composites
- SiC particulate / Si₃N₄ matrix composites
- SiC whisker / AI_2O_3 matrix composites
- SiC whisker / Si_3N_4 matrix composites
- Continuous fiber / glass matrix composites
- Carbon / carbon composites
- SiC / SiC composites
- Oxide / oxide composites.

Ceramic fibres such as SiC and Si_3N_4 use polysilane as the base material. CMCs, in which ceramic or glass matrices are reinforced with continuous fibres, chopped fibres, whiskers, platelets or particulates, are emerging as a class of advanced engineering structural materials. They currently have limited hightemperature applications but a large potential for much wider use in military, aerospace and commercial applications such as energy-efficient systems and transportation.

There are also other specialty CMCs such as nanocomposites (made from reactive powders) and electroceramics. CMCs are unique in that they combine low density with high modulus, strength and toughness (contrasted with monolithic ceramics) and strength retention at high temperatures. Many have good corrosion and erosion characteristics for high temperature applications. CMCs have been used in jet fighters. Industrial uses of CMCs include furnace materials, energy conversion systems, gas turbines and heat engines.

Automotive industry.

Heat exchangers

. . .

- Aerospace and military applications.
- Bearings in missiles.

Other applications include wear parts, such as seals, nozzles, pads, liners, grinding wheels, brakes, etc. For instance, carbon fiber reinforced carbon composites are being used in aircraft brakes.

They are also used in dies and tool bits, medical implants and landbased power and transport engines.



Carbon-Ceramic Matrix Rotors



Multiple-mission spacecrafts necessiate reusable heatshields and heatexposed elements. Ceramic Matrix Composite (CMC) are the most suitable structural heatdurable materials for these functions, carbon fibre reinforced silicon carbide (C/SiC) in particular.

For producing these composites, the carbon fiber mats are imprignated with the Fast-Sol-Gel, a resin based on rapid hydrolysis and polymerization of a mixture of $(Me)_xSi(O-Me)_{4-x}$ monomers. After a gradual heat-pressure process under inert atmosphere the green composites are converted into C-SiC composites. Schematic reaction: $(SiRO_{3/2})_n \rightarrow SiC + CO_2 + H_2O$

In addition such materials require an Oxidation Protection System (OPS) to prevent oxidative damage to the carbon fibres during re-entry. These OPS should reliably protect the C/SiC structures at temperatures up to 1600°C and must remain crack-free over the whole temperature range from approx. 450 to 1600°C. This system consists of the Fast-Sol-Gel resin and ceramic filler like n-Al₂O₃ or n-ZrO₂.



SEM view of hot-pressed (1600°C 30MPa) Fast-Sol-Gel-derived carbon-fabric composites: Fibers extending from molten glass.



SEM view of C/SiC composite with two layers of OPS.

http://www.aac-research.at/products/products_AAC_Service_CeramicMatrix_en.html



BrakeTech Ceramic Matrix Composite (CMC) Rotor on a BST Carbon Fiber wheel, paired with Brembo Monobloc Calipers, custom anodized spacers & bottons and Ohlins Superbike Forks.



The Porsche Carrera GT's carbon-ceramic (SiC) composite disc brake



Ceramic Matrix Composite Turbine Blade



An F-16 Fighting Falcon F100 engine exhaust nozzle with five A500 ceramic matrix composite divergent seals, identified by the yellow arrows. (Air Force photo)

CMCs are excellent candidates for replacing the nickel-based superalloys currently used in exhaust nozzle parts, primarily due to their capacity to withstand the high temperatures and severe operational environment for much longer periods of time with minimal changes in structural behavior.

In examining the feasibility of using the A500 seals on the divergent section of the exhaust nozzles, AFRL researchers are addressing a number of key Air Force issues--one of which involves the performance comparison of CMC parts in flight and during engine ground testing. SPS has developed a novel CMC that uses carbon fibers in a sequentially layered carbide matrix produced via chemical vapor infiltration. Because this resultant matrix is self-sealing, it helps protect the carbon fibers from oxidation. The fibers are woven in a multidimensional, ply-to-ply angle interlock pattern to reduce the chance of delamination.



Braided and unidirectional S-2 Glass and carbon fibers are used to produce forks with different stiffness.



http://matse101.mse.uiuc.edu/

Ceramic matrix composite (CMC) development has lagged behind other composites for two main reasons.

First more of the processing routes for CMCs involve high temperatures and can only be employed with high temperature reinforcements. It follows that it was not until fibres and whiskers of high temperature ceramics, such as silicon carbide, were readily available was there much interest in CMCs. The high temperature properties of the reinforcement are also of importance during service. A major attribute of monolithic ceramics is that they maintain their properties to high temperatures and this characteristic is only retained in CMCs if the reinforcements also have good high temperature properties. Hence, there is only limited interest in toughening ceramics by incorporation of reinforcements of materials, such as ductile metals, that lose their strength and stiffness at intermediate temperatures.



The second factor that has hindered the progress of CMCs is also concerned with the high temperatures usually employed for production. Differences in coefficients of thermal expansion, α , between the matrix and the reinforcement lead to thermal stresses on cooling from the processing temperature.

However, whereas the thermal stresses can generally be relieved in metal matrix composites by plastic deformation of the matrix, this is not possible for CMCs and cracking of the matrix can result.

The nature of the cracking depends on the whether the reinforcement contracts more or less than the matrix on cooling as their determines the character (tensile or compressive) of the local thermal stresses.





INTRODUCTION

Geosynthetics are materials made from various types of polymers, used with geological materials like soil, rock etc. to enhance, improve or modify the behaviour of various civil engineering works.

Geosynthetics are available in a wide range of forms and materials, each to suit a slightly different use. These products have a wide range of applications and are currently used in many geotechnical, transportation, hydraulic, and private development applications including roads, airfields, embankments ,retaining structures, reservoirs, canals, dams, erosion control, sediment control, landfillliners, landfill covers, mining, and agriculture.

Why we use GEOSYNTHETICS

- For improving ground stabilization.
- Pavements: Roads , Parking Bays , Runways(for bearing vehicle loads).
- Heavy duty pavements : Ports and Harbours.
- ✤ For railways.
- ✤ For erosion control.
- For retaining wall and bridge abutment.
- And most important for building foundation improvements.

Geosynthetics are Classified as follows



1. GEO-TEXTILE

Geotextiles are permeable fabrics which when used in association with soil, have the ability to separate, filter, reinforce, protect, or drain.

Characteristics-

- Porous and allow flow of water through it.
- Most used Geosynthetics.
- Available in rolls of 5.6m wide and 50-150m long.



Geotextile fabrics come in two basic forms :





Microscopic View



Uniform and regular interweaving of threads or yarns in two directions.
Regular Visible Construction Pattern.
Function: Soil Separation,
Reinforcement, Load distribution,
Filtration, Drainage
Have high tensile strength and relatively low strain.





Microscopic View



Formed by heat bonding, resin bonding or needle punching.
No visible thread pattern.
Function: Soil separation, stabilization, load distribution, but not used for reinforcement.
They have high strain and stretch considerably under load.

2. GEO-GRIDS

- A Geogrid is geosynthetic material used to reinforce soils and similar materials. Geogrids a commonly used to
- reinforce retaining walls, as well as sub bases or subsoil's below roads or structures.
 below roads

They have open grid like configuration i.e. they have large aperture between individual ribs.
 They have Low strain and stretch about 2% under load.
 Low strain
 Strength is more that other common

geotextiles. **Strength is more**

Function: Used exclusively for reinforcement



How Geogrid Improves the durability of Roads:



• The Pathway deforms after

Use of Geogrid for Soil Reinforcement \rightarrow



All as



Base Reinforcement Geogrid

3. GEO-NETS

- Geonets are also planar products.
- Consists of ribs in two directions.
- Apertures are of diamond shape.
- Thickness is larger than that of geogrids.
- ✤ Are also known as "geospacers".
- Geonets are made of stacked, crisscrossing polymer strands that provide in-plane drainage.
- Two layers of strands are called "biplanar".
- Three layers are called "tri-planar".







APPLICATION

- Erosion control : ribs acts as small check dams to slow down the surface runoffs which decrease erosion potential of water.
- Drainage layers: water flows along the geonets because of large thickness.



4. GEOMEMBRANES

A Geomembrane is very low permeability synthetic membrane barrier used to control fluid or gas migration in a structure, or system.

Thickness impervious

plastic sheet.

Thickness 0.5mm to 3mm approximately.

Used as a fluid barrier in designing drainage systems, etc.

✤Used as damp proof course in floors, roofs etc.





APPLICATION

- Land filling linin
- Canal lining
- Tunnel lining



5. Geosynthetic clay liner

It is a woven fabric-like material, combination of geotextiles and geomembranes used as a barrier for liquid or solid waste

Applied below and above geomembrane layers in landfills

Self repair mechanism.

Provide sub-base support.



6. Geocells

Geocells are 3-dimensional honeycomb-like structures, made of strips of polymer sheet.

CharacteristicsSimilar to geotextiles or geogrids but have depth.
provides both a physical containment of a depth of soil and a transfer of load through
Allow water through it.
Used in slopes with soft sub-grade
Used in erosion control in channels



Use of Geocell in Erosion Control









Geofoam is manufactured into large lightweight blocks by polymeric expansion process. They are large but extremely light materials with gas

filled cells.

✤Low density/ high strength: Geofoam is 1% to 2% the density of soil with equal strength.

✤Quick to install and can be installed during any type of weather.

✤If geofoam comes in contact with a petroleum solvent, it will immediately turn into a glue-type substance, making it unable to support any load.

Untreated geofoam is a Fire hazard





Uses-

within soil embankments built over soft, weak soils;

• under roads, airfield pavements and railway track systems subject to excessive freeze-thaw conditions.

thermal insulation in storage tanks containing cold liquids.

separation, lightweight fill, compressible inclusions,

8. Geocomposites

These are combination of two different types of geosynthetics to take advantage of each

This is prepared to extract all the major properties of the geosynthetics into a single unit with minimum cost.

The various types of Geocomposites

are :-

Geotextile-Geonet Composites Geotextile –

Geomembrane Composites

Geotextile – Geogrid Composites Geomembrane – Geogrid Composite Geotextile-Polymer Core Composite



FUNCTION OF GEOSYNTHETIC MATERIALS: A Comparative Review.

Types Of Geosynthetics	Separation	Re- inforcement	Filtration	Drainage	Containment
Geotextile	YES	YES	YES	YES	
Geogrid		YES			
Geonet				YES	
Geomembrane					YES
G. Clay Liners					YES
Geocells		YES			YES
Geofoam	YES				
Geocomposites	YES	YES	YES	YES	YES

GEOSYNTHETICS AREAS OF Application



- In Roads and Pavements:
 - Subgrade separation and Stabilization,
 - Base Reinforcement,
 - Overlay Stress Absorption and Reinforcement.
- In Subsurface Drainage:
 - Subgrade dewatering,
 - Road base drainage,
 - Structure drainage.
- In Erosion and Sediment Control
 - Hard Armor Systems, Silt Fence.
- In Reinforced Soil Systems:
 - Embankments over soft foundations,
 - Reinforced Steepened slopes,
 - Reinforced soil walls.
- In Seepage control systems

Advantages of Geo-synthetics



- · Cheaper in poduct cost, transport and installation.
- Can be designed (predictability)
- Can be installed quickly with flexibility to construct during short period.
- Consistent over a wide range of soils
- Space Savings
- Material Quality Control More homogeneous than soil and aggregates.
- Better Construction Quality Control at site
- Easy Material Deployment
- Less Environmentally Sensitive
- Improved performance and extended life
- Increased safety factor
- Compatible with field conditions
- Increased service life of flexible pavement section by a factor of 2.5 to 3.0 for weak subgrades (CBR 2%) and by 2.0 to 3.3 for moderate subgrades





Fullerenes consist of 20 hexagonal and 12 pentagonal rings as the basis of an icosohedral symmetry closed cage structure.

- Each carbon atom is bonded to three others and is sp² hybridized.
- Molecule with the largest number of symmetry operations, the most symmetric molecule - 120 symmetry operations



- C60, "Buckminsterfullerene" is a molecule that consists of 60 carbon atoms,
- arranged as 12 pentagons and 20 hexagons.
- The shape is the same as that of a soccer ball: the black pieces of leather are the pentagons, the hexagons are white.

Symmetry of the C60 molecule

- The C60 molecule is highly symmetric, that means one can find many transformations that map the molecule onto itself.
- Symmetry operations for a molecule are rotations around an axis, reflections in a plane, and sometimes so called inversions.
- All symmetry operations must leave the center of mass of the molecule in place, so all rotation axes and mirror planes must go through that point.
- Got three kinds of rotation axes.



CHEMICAL PROPERTIES OF FULLERENE

- Fullerenes are stable, but not totally unreactive.
- The sp²-hybridized carbon atoms, which are at their energy minimum in planar graphite, must be bent to form the closed sphere or tube, which produces angle strain.
- Fullerene is electrophilic addition at 6,6- double bonds, which reduces angle strain by changing sp²-hybridized carbons into sp³-hybridized ones. The change in hybridized orbitals causes the bond angles to decrease from about 120° in the

sp² orbitals to about 109.5° in the

sp³ orbitals. This decrease in bond angles allows for the bonds to bend less when closing the sphere or tube, and thus, the molecule becomes more stable.

• Fullerenes are sparingly soluble in many solvents - aromatics, such as toluene and carbon disulfide



PHYSICAL PROPERTIES OF FULLERENE (C60)

1. **Do not** dissolve in water







3. Soft and slippery



4. Brittle



5. Low melting point solids



FULLERENE:

APPLICATIONS

Cancer treatment

- The surface of fullerene can be 'decorated' by chemotherapeutic agents
- An antibody is attached (detect the unique chemical signature of cancer cell)
- Propel it towards cancerous cells and attach to the surface of tumour
- Deliver its payload

As superconductor

- The pure C_{60} grows in a lattice and is an insulator.
- By placing alkali atoms in the interstitials the crystal becomes metallic and eventually superconducting at low temperatures.

HIV-1 protease (enzyme responsible for the development of the virus)

- Water-soluble derivatives of fullerenes can inhibit it
- Useful in fighting viruses that lead to AIDS

Carbon nanotubes

- Have electrical conductivity 10x better than copper and 100x than steel
- Used in replacing silicon
- Used in synthesis of new compounds that allow unstable substances to become stabilized when incorporated within the tubes

THANK YOU