CSEM's
Materials Monthly
August 2005 Making materials matter

Paperclay fills the gap

Paperclay is a composite ceramic material made by the addition of paper pulp to any type of unfired clay. Conservators at the National Gallery of Australia together with materials researchers at ANU are testing paperclay to see if it might make a suitable gap filler to compensate lost sections in earthenware ceramics.

Here's a problem that's not unusual for a materials conservator: say you have an old, valuable earthenware ceramic bowl you want to put on display in an art gallery but it's missing a large chunk from its side. It doesn't look attractive and the missing piece makes the whole bowl more fragile. What do you do?

In the past you'd probably apply Polyfilla or plaster but these materials have some major disadvantages. Working times are short and filling holes in valuable ceramic objects takes time. Furthermore, portions of the plaster or Polyfilla are easily absorbed into the porous earthenware causing ghosting or staining. The plaster can also sometimes be heavier than the ceramic it's replacing creating further problems.

Now, investigations by conservators at the National Gallery of Australia with assistance by materials scientists at ANU are suggesting that paperclay might be an ideal material to solve these infill problems. The work has also opened up a range of other exciting applications for paperclay.

The business of materials conservation

Materials science plays a crucial role in any large gallery or museum. A knowledge of the structure and chemistry of the materials in the objects on display (or in storage) is essential for the creation of a safe environment for those objects. Materials conservation has two main functions: preventive conservation and restoration (see box on Conservation at the NGA). Materials science is also providing insights on the artists who have created some of the world's great works of art.

When it comes to the restoration of objects the aim is to enhance its aesthetic nature and structural stability. In other words, make it more attractive and safer for display, handling or storage. However, any modifications made to the object need to be identifiable and reversible in order to preserve the historical integrity of the item. You might not like the look of a hole in the side of the bowl but it's an undeniable part of the history of the object.

Consequently, conservators are always on the look out for new materials they can use to repair objects of art but those materials need to meet a wide range of criteria.

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Jaishree Srinivasan (left) and Beata Tworek-Matuszkiewicz in the Objects Section of the Conservation Department at the National Gallery of Australia. At any time they will need to deal with a diverse range of materials. On the day *Materials Monthly* visited this included a turtle shell map, an old Asian metal nut container, a broken glass vase, a deteriorating bark painting, a beaded wall hanging and a range of ceramics.

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Filling that gap

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Filling that hole

When it comes to infilling missing sections in earthenware ceramics, clay is a logical material, having similar properties of strength and weight as the material it's replacing. Unfortunately, it suffers from a high shrinkage rate when fired making it difficult to form shapes that will accurately fill the missing portion.

"A few years ago I had an idea that paperclay might be worth looking at as a gapfiller," says Ms Jaishree Srinivasan, an Objects Conservator at the National Gallery of Australia (NGA). "At the time I was undertaking a course in materials conservation at the University of Canberra, however I was aware of paperclay because of my background as a ceramicist.

"The term paperclay is used to describe any clay body to which processed cellulose fibres in the form of paper pulp have been added. It had gained popularity in the 80s and 90s as an alternative handbuilding material for potters and I thought it would be interesting to test its application in conservation.

"I undertook the initial testing as a research project for my conservation studies with advice and assistance from Dr Zbigniew Stachurski and Mr Tony Flynn from the ANU Department of Engineering. Ms Beata Tworek-Matuszkiewicz was my supervising lecturer at the time.

"These initial investigations suggested paperclay held enormous potential as a gapfiller so I have revisited the project and undertaken a series of further tests. However, now the work is being done from the National Gallery of Australia where Beata and I both work as Objects Conservators. Zbigniew and Tony are still collaborating with us on the work and Dr Roger Heady at the ANU Electron Microscope Unit has also assisted with several scanning electron microscope images of varying mixes of paperclay.

A better mix

"The results from initial testing were very encouraging," says Ms Srinivasan. "We found that even small additions of 2.5% w/w paper pulp to earthenware clay greatly improved its green strength and working properties while still maintaining more than adequate compressive strength when fired. Shrinkage was less of a problem and we found that the paperclay could still be reworked even after it had dried out by simply rewetting the clay. Consequently, even though it might shrink as it dries, it's relatively straightforward to spread it out or add to once it has dried to fill the gap left by the shrinkage.

"The reason paperclay has such good working properties is probably because the cellulose fibres not only act as a 'backbone' for the composite material, but also allow the moisture to pass through the matrix quickly thereby avoiding mechanical shock caused by sudden localized expansions or contractions, resulting in cracking. The fibres also

Conservation at the NGA

The Conservation Department at the National Gallery of Australia (NGA) employs 20 staff, including professionally qualified conservators and technicians who are responsible for the conservation and restoration of works in the collection. The Department is divided into five sections: Paintings, Objects, Textiles, Paper and Preventive Conservation.

The Department is concerned with the treatment, display and storage of works in the collection. In addition, works of art in national and international exhibitions are prepared for travel. The conservator's job is to stabilise the object's condition and slow down the natural deterioration processes. This is done through a variety of treatments of varying complexity, and through preventive conservation measures.

The conservation approach to each object will vary depending on factors such as its physical nature, its cultural significance and artistic intent. All treatments and scientific investigations are documented; all materials used in conservation treatments are tested for long-term stability and reversibility in the future.

Indeed, visitors to the NGA might be surprised at just how much documentation there is with each work of art housed in the gallery. Detailed notes, sketches, maps and photos are kept on the original condition of the object, painting or drawing, what treatment was carried out, what was discovered during the treatment and how the item should be looked after in future.

In terms of preventive conservation, constant monitoring of temperature, humidity and light levels is undertaken throughout the gallery.

"But it's not just ambient atmospheric conditions we're worried about," says Lisa Addison, the Preventive Conservator at the NGA. "We also need to understand what materials are being used near the art, such as in display cases. MDF boards used in display cases, for example, contain formaldehyde, resins and organic acids and emit a range of damaging gases over some time. Acrylic paint, as another example, needs to be left drying for four weeks before a painted surface can be allowed near any of our collection.

"Preventive conservation is taken very seriously at the NGA, and every decision made in the running of the gallery requires the consideration of possible impacts that decision might have on our collection of works. And that goes right down to the type of food served at the openings of new exhibitions. It needs to be served up in small bites that won't break, dribble or leave remnants in our gallery space."

More info: http://www.nga.gov.au

Lisa Addison examines one of the NGA display cases.

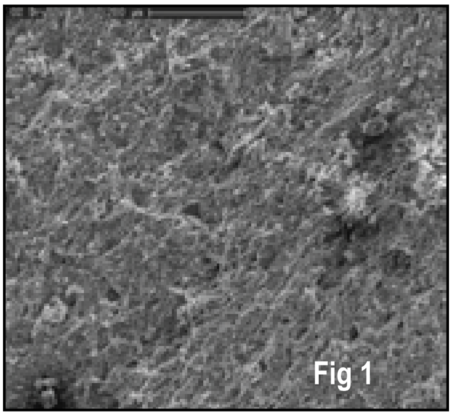

Fig 1

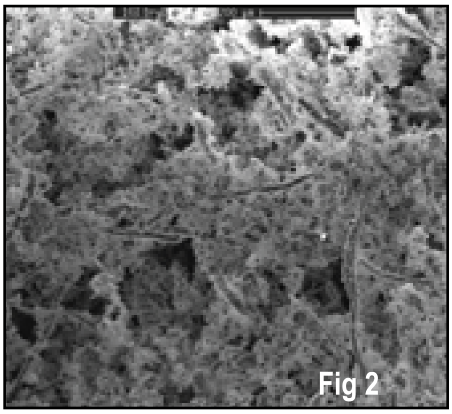

Fig 2

Figure 1 is a scanning electron micrograph showing the fracture face from a raw clay sample at 100X magnification. The surface reveals the presence of numerous voids that are randomly distributed, as well as particles of varied size and distribution. When paper pulp is incorporated into clay, the heterogenity of the material is enhanced considerably as seen in figure 2. The paper fibres are not only randomly distributed through the matrix but also randomly oriented.

make the clay less brittle and give it good flexural-strength properties in the raw state.

"This led to the conclusion that maybe paperclay as a detachable infill material didn't even need to be fired so we have subsequently explored this aspect of the material in our current testing. We found that samples in the range of 1-3% (w/w paper pulp to earthenware clay) display the best overall measured results for working properties and flexural strength, and also displayed adequate compressive strength.

"Our findings suggest considerable promise for raw, unfired paperclay as a gap filler for large losses in earthenware ceramic items. However, it also suggests that unfired paperclay might also serve in a range of other valuable applications.

More holes it can fill

"We believe there is considerable potential for paperclay to be used out in the field on archaeological digs," explains Ms Srinivasan. "It could be used as a temporary infill material to allow incomplete ceramic objects to be patched to increase their structural stability. Paperclay is quite light when dry and is very compact. You could easily carry it around with you as a stack of paperclay sheets. These sheets would then require a bit of water to be workable and can be applied on the spot.

Paperclay being used to stabilise and support the base of a wooden sculpture for display.

"There's also another exciting role it might play in the form of packaging for sensitive objects including archaeological finds and works of art. The sheets can be wrapped around the object being packed forming a 'custom-made' jacket to protect it from knocks and bumps.

"Indeed, such is the versatility and user-friendly nature of paperclay that we feel certain there will be many other applications that we haven't even considered yet."

More info:
Jaishree.Srinivasan@nga.gov.au

Troubles with plastic fantastic

Have you caught up yet with the Pregnant Woman at the National Gallery of Australia? You can't miss her, a giant figure of a naked, pregnant women standing 2.5 m high with her hands over her head. She's the work of Australian-born artist Ron Mueck, and she's constructed of fibreglass, silicone and a range of other synthetic materials. The style is sometimes referred to as hyper real as every feature of the pregnant form is exquisitely captured and appears larger than life.

But how will the component materials from which she was crafted fare over time? Will her evocative hyper reality still be apparent in a decade?

"No-one honestly knows how she will age," says Ms Beata Tworek-Matuszkiewicz, the Senior Objects Conservator at the NGA. "While we have centuries of accumulated knowledge about the behaviour of some materials such as oil paints or wood there's much we don't understand about modern plastics, especially mixes of plastics or plastics with different additives in their structure.

"The Pregnant Woman, for example, uses several different silicones polyester resin, fiberglass, acrylic hair, acrylic paints and so on. It's possible that another resin, such as vinyl resin suggested by materials specialists and the ANU may have been a better choice than polyester resin in building this sculpture in terms of longevity and resistance to deterioration but the initial choice of materials is not something that materials conservators commonly influence. Our job is to find out what was used and how an object can be best looked after.

"Towards this end we're seeking to work with polymer researchers at ANU to devise a protocol for the testing of plastics in art materials at the NGA. The protocol would, with the smallest of sampling, allow us to determine what polymers have been used in an object and then provide information on how each polymer behaves and what is necessary for its preservation at an art gallery.

"If we could devise such a protocol it'd be a major step forward for materials conservators in galleries around the world."

The art of minimal surfaces

What began as an interest in reflective surfaces led one artist to make connections all across the ANU campus.

by Tim Wetherell

Eric Hu began to investigate the artistic potential of reflective surfaces during his Honours year at the ANU School of Art. His early works explored the fascinating effects of internal reflection within spheres which he painstakingly crafted in gilding metal then electroplated with silver. Although Mr Hu was able to create some beautiful works, such as My Kaleidoscope 4, he felt that the single viewing point offered by spheres was restricting. Consequently, when Mr Hu enrolled for a Masters Degree the following year, he began to research more exotic shapes such as those formed when a soap film fills a loop of twisted wire.

(From the left) Eric Hu, Gareth Crook and Gerd Shroeder look at a sculpture built out of minimal surfaces.

It was at this point that Mr Hu began a very productive interaction with Applied Mathematicians Mr Gerd Schroeder, Professor Stephen Hyde and Dr Tim Senden at the Research School of Physical Sciences and Engineering (RSPSE). They too were interested in soap films because surface tension tries to pull the film into a shape that has the minimum possible energy. But the science of surfaces can take one far beyond a single film cell. There are a whole family of possible surfaces, some of which offer the potential to create intertwined double labyrinths. These surfaces are interesting to scientists because they are found in many physical systems including human lungs where the fluids of air and blood need to intertwine over a vast area without actually mixing.

The mathematical surface that particularly caught Mr Hu's artistic eye was an infinite periodic minimal surface known as the diamond surface. Part of its beauty comes from the fact that it consists of two identical, intertwined labyrinths, which can potentially extend out to infinity. However recreating these elegant shapes in solid metal presents a tremendous technical challenge.

Although Mr Hu was able to make small surfaces by hammering metal sheet, this process didn't lend itself to making multiple interlocking cells, which was the direction in which Mr Hu's work was leading. To overcome this, Eric and the math-ematicians designed a minimal-surface press using a 3D computer model. They then had the faces of the press generated in plastic at the University's rapid prototyping facility, with the help of Mr Gilbert Riedelbauch at the Computer Art Studio.

To make the press durable enough to withstand repeated use, Mr Hu then worked with the Sculpture department to cast perfect replicas of the faces of the press in bronze. Using this bronze press, he was able to create a series of cellular minimal surfaces that could be assembled into a portion of the diamond surface.

Mr Hu's work on these surfaces earned him the offer of an exhibition at Sydney's Object Gallery. In order to compliment the smaller works in this show, Eric, has begun work on a large-scale minimal surface sculpture. This required a new press on a much grander scale so Mr Hu took the project to the RSPSE Mechanical workshop. Using Mr Schroeder's mathematical model of the surface and Mr Gareth Crook's expertise in 3D CNC machining, the team was able to create a monster press, capable of withstanding the 30 tons of pressure needed to crush thick metal sheet into the minimal surface cells.

Eric Hu with a purpose built press at RSPSE.

Having finished fine tuning the monster press Eric is now generating large numbers of surface cells and the sculpture is well on the way to completion. Eric's final work, and that of two other ANU silversmiths, can be seen at the Window space, Object gallery in Sydney from 25 March to 7 May 2006.

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More info:
Tim.Wetherell@anu.edu.au

Professor Stephen Hyde (left) and Gerd Shroeder demonstrate some of the amazing properties of diamond surfaces using models produced by the rapid prototyper. See the March 2003 issue of *Materials Monthly* for more information on these amazing surfaces.

On reflection

a better way of picking pigments

Ms Kubik has compiled an extensive database of reflectance signatures of most common pigments used in painting. Pictured here is part of the National Archive of Australia's Kremer pigment collection.

When it comes to the conservation of paintings a basic problem facing materials conservators is knowing what kind of paint has been used. Pigments of the same colour are often composed of significantly different substances, and in order to conserve or restore a painting it's important to know what you're working with.

The traditional approach has been to take a minute sample of the unknown pigment and analysing it under the microscope or using more destructive analysis techniques. Small sections may also be studied using reflectance spectroscopy – shining energy of specific wavelengths on the sample and then measuring how much is reflected or absorbed. This will vary according to what the paint is composed of.

"Each pigment has its own characteristic reflectance signature," says Maria Kubik, a paintings conservator investigating the spectroscopic identification of pigments for art conservation. She is also currently a doctoral student at the Research School of Chemistry (RSC). "If you can create a database of the signatures for most of the possible pigments used in paintings then it's possible to work out what an unknown pigment is by comparing its signature with your database."

In recent years she has set up and applied a number of databases using Raman and UV fluorescence spectroscopy, but she has struck a problem that faces materials conservators everywhere at some time.

"Unless you have expensive portable equipment, Raman and UV fluorescence spectroscopy require a small sample of the unknown paint to be taken away for testing in a lab," say Ms Kubik. "While this might help you identify what components a paint is made from, it's achieved at the expense of a tiny portion of the painting itself. At most galleries this simply isn't acceptable so the challenge has been to come up with some non-destructive form of testing that can rapidly and accurately assess what pigments have used in a paint mix.

"I wondered if I could apply imaging spectroscopy in pigment identification to overcome this problem. Imaging spectroscopy is used extensively in remote sensing where a range of information is extracted from the light reflected from the Earth's surface. However, this technology has only been applied to art conservation recently, and its application in this field is still only being developed.

"Unfortunately, while the approach looked promising, it quickly became apparent that the equipment used in remote sensing was not suitable for my purposes. It might work at distances measured in kilometres but assessing paints involved working at distances of less than a metre. The system I needed also had to portable so it could be taken from gallery to gallery.

Maria Kubik and the imaging spectroscopy system she has developed to measure known pigments in an effort of determine the composition of unidentified paints in-situ.

"Consequently, I've had to put together my own equipment. This is where it has been a big advantage working in the Laser and Optical Spectroscopy group at RSC. Not only do I have access to excellent spectroscopy facilities but I'm also surrounded by experts in this area, such as the group's leader Professor Elmars Krausz. They've been able to provide invaluable advice on what I might use and how we might put such a system together."

The system Ms Kubik has developed is deceptively simple. It uses two slide projectors as a light source illuminating the canvas or the sample paints being assessed. Light reflected off the target then passes through a series of light filters and is measured using a Charge Coupled Device (CCD) camera.

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On reflection

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"By combining the three technologies of digital imaging, reflectance spectroscopy, and multivariate computer analysis, it's possible to determine the composition of paints in-situ," explains Ms Kubik. "This is quite similar to infrared reflectance technology, and involves using a CCD camera for image capture, in this case across the ultraviolet, visible and near infrared regions. In combination with narrow-band interference filters, a series of images is built up into a multi-spectral datacube. Reflectance spectra of individual areas of a painting may then be obtained by slicing across the datacube.

"In many cases these spectra can be used to identify and differentiate between pigments, for example, blues with otherwise the same hue. Unique reflectance spectra also permit developing spatial maps of each pigment used across a given painting.

"I'm confident that the portable and non-destructive nature of this system will make it of enormous value to materials conservators."

Ms Kubik is continuing to refine the system and build its reference database. In the longer term she hopes to develop an imaging system that can capture UV fluorescence, visible spectral reflectance and IR reflectance. This would enable the complete optical characterisation of paintings by one system.

Maria in front of a William Dargie study from the Australian War Memorial which is being studied for its pigment makeup. She found she was able to determine the unknown paints by analysing their reflectance.

"If we could build that," says Ms Kubik, " we would really have a powerful tool for conservation."

More info:
kubik@rsc.anu.edu.au

2005 CSEM Prizes

Do you know an undergraduate student who might be in the running for a CSEM Prize in 2005?

Now in its fourth year, the CSEM Prizes seek to acknowledge excellence in materials science and engineering at an undergraduate level. There are two prizes, one for the best Honours thesis in the field of science of materials and one for the best application of materials.

Each prize is worth $2,000. The beauty of the awards is that they don't require the students to go to much additional work to enter. All they have to do is submit a copy of their final year thesis to the Director of CSEM by the 30 November.

See the CSEM homepage for full details.

More info: http://www.anu.edu.au/CSEM/

Contacting CSEM

Director
Dr Zbigniew Stachurski
Phone: (02) 6125 5681
Email: Zbigniew.Stachurski@anu.edu.au

Editor, *Materials Monthly*
David Salt
Phone: (02) 6125 3525
Email: David.Salt@anu.edu.au

Electronic copies of Materials Monthly, useful links and additional information about CSEM can be found at our website: www.anu.edu.au/CSEM

CSEM Office

Fax: (02) 6125 0506

Phone: (02) 6125 3525

Postal: CSEM
Dept of Engineering
Bld #32, ANU ACT 0200

Location: Room E212, Dept of Engineering, (Bld #32), cnr of North Road and University Ave, ANU

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