



JOURNAL OF THE OIL AND COLOUR CHEMISTS' ASSOCIATION

JOCCA



Annual
Index
Vol. 71
1988

■ Painting of Concrete

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JOURNAL OF THE OIL AND COLOUR CHEMISTS' ASSOCIATION

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Contents

Vol. 71 No. 12

DECEMBER 1988

Chester Conference Column.....	395
by A. C. Jolly	
News.....	396
<i>Feature: Painting of Concrete</i>	
Editorial: Concrete coatings	401
by G. W. Rothwell	
Requirements of coatings.....	403
by P. C. Robery	
Polymer emulsion based systems for the protection and repair of concrete	407
by P. B. Jones	
Concrete protection with methacrylate resins	410
by E. Sattler	
Two-pack acrylic urethane systems.....	413
by K. O'Hara	
Two-pack epoxy coatings as protection for concrete structures.....	415
by N. S. Moss	
A survey of Romano-British wallplaster	417
by G. C. Morgan	
<i>Transactions and Communications:</i>	
Maintenance painting of exterior timber.....	419
by J. Boxall and G. A. Smith	
From the General Secretary	429
OCCA Meetings.....	430
OCCA News.....	432
Professional Grade Register	433
Index	436

Cover: Epoxy coatings used to protect an underground water storage reservoir. Photograph courtesy of Ciba Geigy Plastics.

Forthcoming Features: Feb - Paint Production, Mar - Pigments, April - Automotive/Industrial Coatings. Contributions are welcomed at least five weeks prior to publication date.

Oil and Colour Chemists' Association

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OCCA CONFERENCE 1989

“Profitable Research and Development”

will be held at the

Chester Grosvenor Hotel

on

21 — 24 June 1989

KEYNOTE SPEAKER

Mr. D. Pirret, General Manager, Resins & Materials, Shell UK Ltd.

LECTURERS

Dr. Campus, BP Chemicals

Dr. I. A. Macpherson, Ciba Geigy Pigments plc

Mr. Charity, FIRA

Mr. J. Gent, Fulmer Yarsley Ltd.

Mr. A. J. Hinton, Hinton Safety Consultants

Dr. B. Lane, ICI Chemicals & Polymers

Mr. T. Hughes, Liquid Polymers plc

Mr. Tulley-Turner, Management Consultant

Mr. E. V. Carter and Dr. R. D. Lauden,
MPLC Laboratories plc

Mr. T. Kobayshi, Mr. T. Terada and
Mr. S. Ikeda, Nippon Paint Co. Ltd., Japan

Mr. L. Banks, PDQ Testing Ltd.

Mr. S. Nordberg, Perstorp AB, Sweden
PIRA

Mr. D. Wallbridge, PRA
Shell Chemicals

Dr. S. Goethe, Wilhelm Beckers, Sweden

Associated with the Conference will be a Mini-Exhibition, for information on this, contact Chris Pacey-Day on 01-908 1086

The Conference Brochure will be available early in 1989

Chester Conference Column

It may come as a surprise to some of you, indeed this includes a few prominent OCCA-ites, to know that there has been a Conference Column in *JOCCA* ever since the Eastbourne Conference ended. In the issues of the last 18 months I have tried to give an account of the build-up of the Chester event as it happened.

In the light of the above it may well be worthwhile therefore almost repeating, in this and future columns, some of past texts, e.g. "Where is Chester?".

By the time you read this it is quite probable that you will have seen the official brochure for the 1989 Chester Conference and this will give most of the details you need. As last month's column showed the cost of attending is remarkably low and represents excellent value.

One of the first items to which I addressed myself was to help those who did not know where Chester was. Some of that information is repeated below.

Chester is a very attractive city sited above the picturesque River Dee and, whilst its Roman origins are evidenced by the widespread occurrence of structures of that time, it is also very well appointed in terms of modern expectancy (the ladies will certainly approve!). It is the home of the Duke of Westminster whose hotel, the Chester Grosvenor, is its Conference Centre. The accompanying extract tells the rest.

Chester is

1. on the UK motorwork complex
2. 35 minutes (by motorway M56) from Manchester airport.

Travelling times are approximately as follows:

"T" by Train, "R" by Road

London	3 hrs (T)	3½ hrs (R)
Leeds	2 hrs 10 mins (T)	1½ hrs (R)
Glasgow	4¼ hrs (T)*	2¾ hrs (R)
Bristol	3¾ hrs (T)*	2¼ hrs (R)

* includes changing trains



Town Crier of Chester

Social Programme

Wednesday evening (June 21)

The Ale Trail (a now famous series of tours around Chester's genuinely historic pubs with a very professional guide and with astounding surprises).

Thursday morning (June 22)

Tour of the City and its Roman Walls (an amazingly absorbing experience).

Thursday afternoon (June 22)

Coach Trip into the Welsh mountains with tea in Llangollen.

Thursday evening (June 22)

A few hours on board a riverboat through the Duke of Westminster's estate with good food and with a restrained jazz band.

Friday morning (June 23)

To Stapeley Water Gardens and The Palms Tropical Oasis (an experience unique to the UK—seeing is believing!).

Friday afternoon (June 23)

A visit to the Chester Heritage Centre (for as long as you like it the hairdressing appointment presses!).

Friday evening (June 23)

Reception, Dinner and Dance (hopefully with The Duke and Duchess of Westminster, definitely with the Lord Bishop of Chester and the Lord Mayor of Chester and their wives).

The Town Crier of Chester will assist one of Her Majesty's Corps of Toastmasters in the more ceremonial occasions.

A. C. Jolly ■



Eastgate Street, Chester



Lady Diana Riverboat



River Dee, Chester

PA's Open Tech still growing

The self-educating distance learning packages in Surface Coatings Technology, produced by the Paintmakers' Association, continue to grow in quantity, support and recognition.

Two further modules are being produced specifically for employees working with Powder Coatings. Module 09 (60 hours study) will be for those who wish to know about the manufacture, application and some basic testing of Powder Coatings, whilst Module 10 (35 hours) will deal with the ingredients used and the formulation principles. Both will have some details of Thermoplastic materials as well as Thermosetting. It is suggested that these two modules would follow the Module 01 on Basic Technology of Surface Coatings, and also that a complete package may be concluded by studying the 30 hour Module 06 on Coatings Evaluation. These modules should be available by March 1989.

Support for the programme has continued to the point where there is now a record number of GB students involved, ie over one hundred and seventy, so that to date nearly five hundred students have studied over eleven hundred modules, of which 80% have resulted in certificates of satisfactory completion. Seven Tutors are now involved to cover the various geographical areas including Eire. Some overseas agencies have now been set up, including their use by the South African Paintmakers' Association who have over one hundred students. Other similar bodies are encouraged to make contact with the PA to ascertain how they could obtain a sub-licence or agency.

Whilst the ten modules are all offered as discrete packages for which individual certificates are awarded, and therefore this is not to be seen as a total course, the Surface Coatings Industry is accepting these as one of the few routes now open for the study of Surface Coatings. It is therefore a possible route to OCCA's professional qualifications, eg LTSC and is also being used as a standard in promotion, recruitment and grading considerations.

For full details please contact Don Clement at the Student Administration office, Paintmakers' Association of GB Ltd, Alembic House, 93 Albert Embankment, London, SE1 7TY.

Haeffner new pigment distribution agreement

Haeffner & Company Ltd have been appointed as sole stockists and distributors in the UK and Eire for the range of pigments manufactured in Spain by Colores Hispania SA.

These include the Actirox and Hispafos non-toxic anti-corrosive pigments produced at the Colores factory in Barcelona and the Termodur range of heat resistant chromes specially formulated for powder coatings.

Anchor acquires Casamid

Anchor Chemical has taken over the manufacture and supply of the Casamid range of liquid curing agents until recently supplied by Thomas Swan and Co Ltd. This range of curing agents includes

water-dispersible and liquid amine products designed primarily for ambient-temperature cure of epoxy resins. Dr Colin Tilley, joint managing director of the Anchor Chemical Group, commenting on the development, said: "The purchase of the Casamid range brings the best water-dispersible technology currently available to the Group. It strengthens our product line further and will enable us to expand this market sector particularly within the Far Eastern and American markets."

Dussek Campbell gain BS 5750 Part 1

Dussek Campbell Ltd, a key company in Burmah Oil's speciality chemicals division, has been assessed and approved to the level of BS 5750 Part 1. Burmah Speciality Chemicals is one of

Burmah's Oil's main strategic trading operations. It consists of five divisions - Coatings, of which Dussek Campbell forms the main part, Adhesives, Printing Inks, Sealants and Water Management.

BP Japan MA plant

A joint venture between Mitsui Toatsu Chemicals Inc (Japan) and the Sohio Division of BP Chemicals has announced the successful early start-up of a 10,000 tonne Maleic Anhydride (MA) plant in Osaka, Japan. J Douglas Campbell, Sohio Division president, commented that the plant will serve as feedstock to meet Mitsui Toatsu's internal needs for unsaturated polyester resin production.

BRE launch technical consultancy

The BRE has recently launched a technical consultancy aimed at the construction industry, its professions and manufacturers of construction products. For construction products manufacturers' assistance with the development and evaluation of new products will be undertaken drawing on BRE's fundamental understanding of materials performance and BRE's long experience in the behaviour of materials and components in use. For further information and brochures on the Technical Consultancy call the Central Marketing Unit on 0923 664800.

Costar I on course

DSET Laboratories, Inc of Phoenix, Arizona has announced that 42 international companies have agreed to participate in its Costar I Multiclient Weathering Research Programme.

The participants include eight car manufacturers, six automobile materials suppliers, six building product, eleven paint and eleven plastics/polymer manufacturers. Countries represented include Canada, France, Germany, Italy, Japan, the Netherlands, Sweden, the UK and the USA.

COSTAR I (Correlation Of Solar and Thermal Aspects of WeatherRing) is designed to establish the relationship between ultraviolet radiation and the effective exposure temperature in weathering-induced materials degradation processes. Plastics, polymeric building materials, coil coatings, and automotive fabrics, paints and interior trim have been selected for study in COSTAR I. The principal goal of COSTAR I is to develop new tools to aid in the realization of meaningful correlation between accelerated and real-time exposure tests, and between real-time exposure tests at the same and different outdoor sites. Data obtained from the program will be used to develop life-prediction methodologies and models based on the results of the correlation studies.

Degussa purchases US carbon black plants

Degussa AG of Frankfurt am Main, W Germany, has purchased for \$58.5m the carbon black business of Ashland Oil Inc of Kentucky, USA, making Degussa the second largest world producer. The acquisition includes Ashland's plants in Ivanhoe, Louisiana, Aransas Pass, Texas and Belpre, Ohio, which have a total annual capacity of 200,000 tons.

Degussa is the longest-established European manufacturer of this material, and following the acquisition of five European carbon black plants from the Phillips Petroleum Company in 1986 has further consolidated its position as a carbon black producer on an international scale. The seven carbon black plants operated by Degussa or with its participation in the Federal Republic of Germany, France, Holland, Sweden, Italy and South Africa have a total annual capacity of 520,000 tons.

Degussa plans to extend Ashland's production which was formerly for the rubber industry into pigment carbon blacks for the printing ink, plastic and paint industries; these branches were previously supplied from West Germany.

New bodyshop computer system from ICI Autocolor

An advanced computer management system, specifically developed for use in bodyshops, has been launched by ICI Autocolor as part of the Company's "Helping Grow Your Business" programme. The new system, known as Shopwatch, is capable of managing all standard bodyshop requirements such as estimating, parts ordering, job cards and invoicing as well as providing more sophisticated functions such as profitability analysis. Shopwatch provides a detailed and flexible method of managing bodyshop throughput and also provides valuable business information for bodyshop owners or managers on the performance, strengths and weaknesses of the bodyshop.

Manders acquires General Decorating Supplies

Manders (Holdings) plc announces the acquisition of General Decorating Supplies (GDS) and a related freehold retail site in Henley-on-Thames (which is separately owned by the proprietors of GDS). The agreed purchase consideration is £2.5 m. GDS operates as a paint merchant based in Reading, and as a retail outlet in the centre of Henley-on-Thames. Manders and GDS have had a trading relationship for a number of years.

Roger Akers, chief executive of Manders (Holdings) plc, says: "The acquisition of GDS will improve Manders' penetration of the Home Counties for our trade paint sold under the Manders brand and provide a further opportunity for the expansion of our retail brand, Trend."

**OCCA
CHESTER
CONFERENCE 1989
See Page 395**

Products

BASF hard-dri inks

BASF Coatings + Inks has introduced a Hard-Dri Series for printing applications involving impervious substrates such as foil and synthetic papers, where a fast-drying ink is essential. The Hard-Dri Series combines a unique blend of polymer science and surface chemistry to give outstanding adhesion. Because drying is by oxidation, press standing times should be minimised to avoid drying on the rollers says the company. The Series comprises black, magenta, cyan and yellow, available in 1 kg vacuum packed tins.

For further information Enter L101

Molecular sieve pastes

Croxton + Garry Ltd has available molecular sieve pastes called Garosorb which are effective dissiccants used to prevent blistering and ensure trouble-free curing in solvent-free one-pack and two-pack PU systems. End uses include sealants, adhesives and surface coatings. These pastes are 50% w/w dispersions of a molecular sieve powder in a castor oil carrier and are distributed in two grades made from 3A° and 4A° powders.

For further information Enter L102

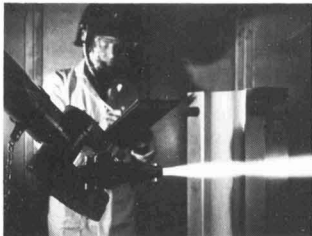
Advances in bimetallic coatings

APV, the world's largest manufacturer of food and chemical processing equipment, has developed a second generation bimetallic wear coating representing a major advance over existing bimetallic coating technology. The wear coating, designated Borcoat G3, has been developed specifically for extruders used in the chemical and food processing industries. The process is however equally applicable for any applications where extreme wear and corrosion are limiting factors.

The Borcoat system is a two stage

powder deposition and heat treatment process. Its revolutionary nature lies in the heat treatment method, known as Hot Isostatic Pressing. The coating consists of a dispersion of Tungsten Carbide particles in a matrix of Nickel Chrome Boride. It has excellent resistance to wear and corrosion. The Hot Isostatic Pressing process produces a 100% dense coating, diffusion bonded to the substrate, which will not crack or chip, even under the most severe conditions.

Using Borcoat coatings, the life of conventional nitrided carbon steel twin screw extruder barrels has been extended from a few hundred hours to upwards of several thousand hours. The Borcoat system can be used to improve the performance of a wide range of components including pumps for abrasive slurries, heat exchangers, drill bits used in the oil industry, and all applications where wear and corrosion reduce component life.



Borcoat powder coating flame sprayed onto the surface to be coated using a computer controlled robot.

For further information Enter L103

Equipment

New colour matching spectrophotometer

By coupling an MTS spectrophotometer to an IBM compatible PC and a high-resolution colour monitor, the French company MTS Colorimétrie has created a powerful tool for analysing and comparing colours. The system's software makes it specifically useful for solving manufacturing problems in the ink and paint industries. The MTS unit is based on the company's own spectrophotometer, but the key

Conductive coatings – a growing new market for paints

Interference shielding coatings are becoming increasingly important to the manufacturers of electronic equipment since this type of device can be seriously affected by radiofrequency and electromagnetic interference generated by natural phenomena, such as lightning, and also by other electronic devices. This is especially significant in aerospace, military and automotive applications where faulty electronics can endanger lives.

Traditionally, electronics components housings made in metal provided some shielding from interference because of their electrical conductivity. The growing use of plastics housings, however, is creating a new market for conductive coatings which must be applied to the plastics housings to provide the necessary shielding. This rapidly expanding market is fast becoming the subject of both user specification and government legislation.

Metal spraying and electroplating techniques have been used for shielding coatings but paint-based systems offers users many advantages. The addition of conductive pigments to paints results in excellent shielding performance at a competitive cost. Also the coatings are compatible with other finishing operations and can be applied to a wide variety of component and housing shapes. Capital costs for the equipment required to apply the coatings are also attractive.

Hart Coating Technology is the UK distributor for the Novamet range of conductive pigments developed specifically for this application. These are manufactured in the USA by Novamet Speciality Products Corporation, part of the Canadian-based Inco Ltd, the western world's leading nickel producer. The range includes nickel particulate materials for cost-effective general shielding applications, together with silver-coated nickel and copper products for aerospace and military applications where a very high level of electronic shielding is needed. The silver-coated products offer very high conductivity at considerably lower cost than pure silver.

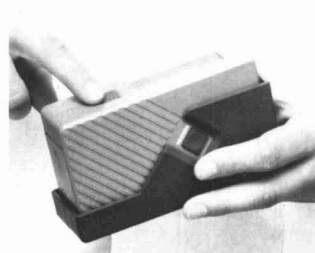
For further information Enter L104

feature of this system is the software which is available in French, English and German versions and can also be used to drive other spectrophotometers.

For further information Enter L105

New Byk portable glossmeter

Micro-gloss available from Byk Labotron is claimed to be the smallest currently available pocket-sized portable glossmeter, which is suitable for measuring painted and coated materials such as metals, wood, plastics and paper products. It is the first and only gloss measuring unit in a holder with a securely mounted high gloss standard. In this holder it is automatically calibrated within seconds by simply pressing two buttons. After calibration the micro-gloss is removed from the holder and ready for measurement. The various international gloss standards recommend an examinee to measure on at least three



Byk micro-gloss

different places and afterwards to use the mean value for assessing the gloss. With the help of the statistics programme of the micro-gloss the mean value is shown immediately on the display. Besides single measurement, up to 99 measured values can be taken and stored by the micro-gloss memory.

For further information Enter L106

Compact automatic viscosity flowcup

As a response to customers' requests, Sheen Instruments has



Sheen Autovisc 450

made major design changes to its Autovisc 450 automatic flowcup viscosity measuring instrument. It now occupies only half the lab bench space of the former model, with flowcup holder and all control features being mounted in the same unit. The flowcup is placed in the holder at the top of the Autovisc 450 and filled with the sample to be tested. The flow is started and timed automatically by pushing the start button on the flow-time controller: timing is stopped when the efflux breaks as required by all international standards.

For further information Enter L107

Portable batching system for viscous liquids

A new portable batching system for viscous liquids is announced by Kecol Pumps Ltd and is designed for transferring pre-set quantities from drums, containers or bulk tanks to mixing vessels etc. The control unit is very simple to operate and once the fine digit counter has been preset and the start button pressed, the pump

Kecol control system and power lift.



For further information Enter L109

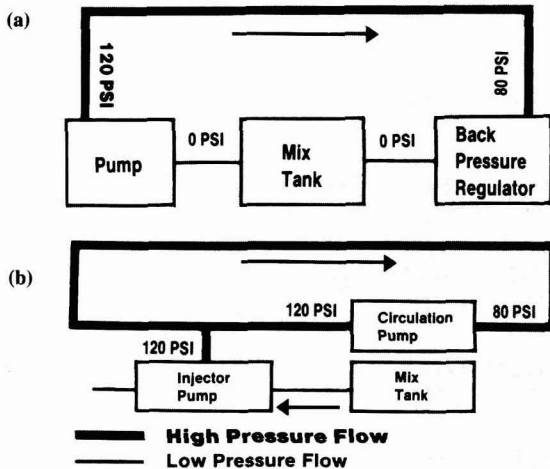
New Graco circulating system

The latest loop injection paint circulating system from world fluids handling specialists Graco claims energy savings of up to 60%.

Normally the pressure to circulate paint round a system is equal to pump pressure minus back pressure. Back pressure keeps the overall system high enough to provide a satisfactory flow rate to automatic colour changes and similar devices.

Graco UK Ltd have done away with the back pressure regulator using an additional pump instead to inject paint into the system to replenish the volume lost by spraying. This additional pump only operates on demand, and since there is no forced reduction in main system pressure, energy savings as high as 60% can be achieved. Other benefits include less paint degradation, and a back up system by virtue of having two pumps.

Several companies in the USA and Europe have already been licensed and are using this patented process, and it is now available in the UK.



(a) Traditional pumping system (b) Graco loop injection circulation system (saving 80 psi).

For further information Enter L109

operates automatically until the required amount has been dispensed. At the end of the cycle the pump is automatically shut off until the start button is pressed. The photograph shows the control system mounted on a Kecol "Powerlift" unit which enables the pump to be raised and lowered into the drum.

For further information Enter L108

Simplified solvent dispensing

Hill has introduced a hand operated solvent dispensing pump known as the Model 840. The pump is designed for transferring paint thinners, trichloroethylene, acetone, benzene and similar solvents from 25 litre containers but



Hill solvent dispenser

may also be adapted to fit almost any container up to a 205 litre drum. Of all brass construction with a single adjustable PTFE seal, the pump is also suitable for dispensing oils and water based fluids, such as cleaning fluids. It discharges approximately 850 mls per stroke on the upstroke.

For further information Enter L110

Light temperature sensing

The problems of achieving accurate temperature profiles in large scale and difficult environments in chemical manufacture are solved by the Distributed Temperature Sensor (DTS) from York Ltd. The DTS uses fibre optic cable as a sensor and so offers major benefits over traditional fixed point devices. It is flexible, easy to install, needs no maintenance and so dramatically reduces operating costs. The DTS consists of a controlling black box, upto 4 loops of standard fibre optic cable, each up to 2 km in length, and a desktop PC.

For further information Enter L111

Improved corrugated printing

Until recently, one of the most common problems experienced by corrugated packaging companies has been poor print quality. This is due largely to over- or under-inking of printing rollers, caused by a high solids content and viscosity level in inks used for this purpose. Even tried and tested Anilox roll ink distribution technology was hard pressed to cope. Now Roto-Flo's cells new from M. A. Buckley Group Ltd are engraved at 26° to the roll axis. The cells are parallelograms in an offset pattern instead of the standard square cell that is in an aligned pattern. The alternating channel between these cells allows improved receptibility and release of ink at all viscosities and machine speeds.

For further information Enter L112

Meetings

COSHH 89

The COSHH 89 exhibition will be held at the New Connaught Rooms on 17-18 January 1989. This exhibition will feature leading companies displaying instruments for environmental analysis, particle size analysis and noise and pollution control. For further information contact Bill Broughton on 0727 31337.

COSHH International

The International Professional Association for Environmental Affairs is organising a one-day Symposium on 18 January 1989 at the Connaught Rooms, London, in the context of COSHH International Exhibition and Conferences. The title of the symposium is "The environmental and international dimensions of hazardous substances control." For further information call Christine Smith on 01-982 3637.

Technicians viscometry training course

A two-day course will be held on 7-8 February 1989 by the Warren Spring Laboratory, Stevenage, Herts, for technicians and experimental workers on the latest developments in the operation and recommended practice for viscosity/non-Newtonian flow measurement on the instruments they routinely use. Participants will be introduced to other viscometers included in our comprehensive range and will obtain information about the latest models on the market. For further information contact Miss P. Madhvi on (0438) 741122.

Literature

BS 6952 Part 1:1988

"Exterior wood coating systems" Part 1. Guide to classification and selection. This Part of BS 6952 has been prepared under the direction of the Pigments, Paints and Varnishes Standards Committee. It gives guidance on the classification and selection of exterior coatings including stains, varnishes and paints for timber. In recent years there has been a proliferation of claims and terms concerning wood coatings, which has caused confusion. Descriptive names for coating systems cut across technical, functional and end use categories making it difficult to devise an unequivocal simple terminology applicable to all

product types. This Part of BS 6952 attempts to avoid this problem by separately defining categories of appearance and end use but with no assumptions on usage suitability. Copies of BS 6952:Pt 1 are available from BSI Sales on 0908-220022.

Literature miscellaneous

Contrapol Ltd new brochure on Thermal Fluid Heating.

For further information Enter L113

Perkin-Elmer Guide to Techniques and Applications of Atomic Spectroscopy

For further information Enter L114

Grantham Electrical vibratory screens leaflets.

For further information Enter L115

People

New head for BRI Inorganics

The Building Research Establishment has appointed Dr Philip Nixon, a leading expert on alkali aggregate reaction in concrete, Head of the Inorganic Materials Division. Dr Nixon joined the Building Research Station in 1970 and in 1978 became Head of the Silicate Chemistry Section. Dr Nixon has recently been appointed Chairman of the BSI Committee on aggregates and he is currently engaged in steering the UK effort towards the European standardization of aggregates.

Perfectos appointments

Perfectos UK manufacturer of printing inks for fabric labels has announced the following appointments: Mr Stu Gunn to the position of Works Director. Stu has worked for the Company since its commencement 18 years ago and is now responsible for all production aspects.

Mr Tony Cox, also a long serving member of the Perfectos team, has been appointed Production Manager.

Mr Neil Westley now takes over the position as Assistant Production Manager. ■

Concrete Coatings

The mineral materials of good quality concrete are inherently durable. Colour, texture and surfacing requirements for architectural purposes can be accommodated. The flexibility for design and construction has led to almost universal acceptance for building and civil engineering. Nevertheless, when concrete is subjected to the rigours of weather and environment, loss of appearance, deterioration of surface and even disintegration can occur.

For many years coatings have been applied for aesthetic reasons. Depending on design and environmental requirements weatherproofing treatments have been widely used also and more durable paints have been produced. The need to protect normally durable structural concrete by coatings has been slower to develop.

Increasing use of steel-reinforced concrete in modern building has led however to a proliferation of deterioration problems associated with reinforcement corrosion. These are related to specification and quality of concrete, depth of protective cover, efficiency in placing and curing, or to factors in the design of structure or environmental exposure. Concrete, both pre- or site-cast, can be affected in virtually all types of existing buildings by loss of protective alkalinity due to reaction with atmospheric carbon dioxide.

Carbonation is dependent principally on permeation rate. When the depth of penetration reaches the level of reinforcement steel corrosion can start in wet, and especially saline, conditions. Rusting may appear at the surface but, more insidiously, the pressure of corrosion products can cause cracking and spalling. Naturally the more permeable, lower cover and vulnerable areas are first affected. Surveys often indicate that loss of alkalinity has not reached the steel in many areas. It is possible to calculate the rate of carbonation and predict its future course.

Effective repairs are needed in the corroded regions and further protection against penetration of carbon dioxide, water and other aggressive agents must be considered, both here and elsewhere, to ensure future satisfactory life. Suitable barrier coatings provide a logical option. The number of cases requiring such protection is growing.

There is more than 10 years' experience with some types of coatings in this field, enough to establish their performance and potential in preventing or reducing carbonation. In the last decade many new systems have been introduced and the need to continue evaluations remains. The appropriate choice, specification and application of coatings is very important.

The binder must resist the alkalinity of cement materials, water, weathering conditions, uv radiation, etc. The coating must wet and adhere to a variety of minerals in even a normal concrete. The substrate will undergo thermal movement due to atmospheric changes, and possibly ageing and structural movements. Some flexibility, retained on ageing, is desirable in all coatings but additional provision may be required for joints, cracks, etc. Durability of 5-10 years has been generally acceptable for decorative coatings on accessible surfaces. Developments have produced coatings which, applied properly on sound concrete surfaces, can in normal conditions last beyond 10 years. This level of durability is essential for protective coating for concrete.

There are special concrete surfaces which because of type, age, etc, may require individual treatment. The range of cements, aggregates and other constituents in more general use is so wide however that great care is still necessary in assessing the characteristics of the concrete as a substrate for coating. Porosity is a variable factor, from sub-micron structure to crevices with up to 20 mm exposed aggregates. Texture, roughness, casting defects, blow-holes, micro-cracks, etc, all have to be considered. The incorporation of sealer, filler or levelling coat into the system may be required.

The principal barrier coating must have sufficient thickness and integrity to provide adequate resistance to carbon dioxide, $R(\text{CO}_2)$, and water vapour, $R(\text{H}_2\text{O})$. In the absence of formal standards criteria have been derived from experience of standard permeability testing of coating systems, and evaluation of their performance in relation to concrete. The values generally accepted in Europe, first proposed by Prof H. Klopfer of Dortmund Univ, are
 $R(\text{CO}_2)$: Resistance to CO_2 to be not less than that of 50 metres of still air;
 $R(\text{H}_2\text{O})$: Resistance to water vapour to be not greater than that of 4 metres of still air.

It can be deduced that for CO_2 the resistance is approximately that of 150 mm of average concrete. For water vapour the value can be related to acceptable diffusion rates for wall structures and seems reasonable for such a low water transport substance as dense concrete. At these levels coatings should also be resistant to penetration of liquid water and of salts.

The coating resistance is directly dependent on the film thickness. To achieve the resistance criterion with lower thickness requires a higher resistivity. The application of a sound, uniform coating on such a variable substrate as concrete requires care. A mean coating thickness below 200 micro-metres could make film integrity requirements critical. It is in any case advisable to build up the total required thickness in two or more coats to minimise the effect of film defects. Control of application by careful regulation of coating coverage is crucial.

Tests have shown that many types of coating, properly formulated and applied, can achieve CO_2 resistance. Compatibility and durability limitations reduce the choice. There is still a wide range including epoxides, polyurethanes, acrylics, acrylic-modified polymers, chlorinated and synthetic rubbers, and durable emulsions based on acrylic, vinyl, or copolymers. In the UK testing and certification of products is carried out by the British Board of Agreement according to the well-established procedures of MOATs 24 and 33. There are corresponding Union of Agreement and Bureau Veritas procedures in Europe.

Recognition of causes of corrosion of reinforced concrete has led to revision of the Code of Practice BS 8110: The structural use of concrete. Improved future performance of new concrete should result but consideration of use of protective coatings in some severer situations could still be worthwhile.

There are areas of the subject of concrete protection where more research data is desirable. These include materials development, long term evaluation of protection mechanisms and benefits, and testing procedures. BRE has an ongoing research programme and may be able to extend this work via its recently initiated Technical Consultancy scheme.

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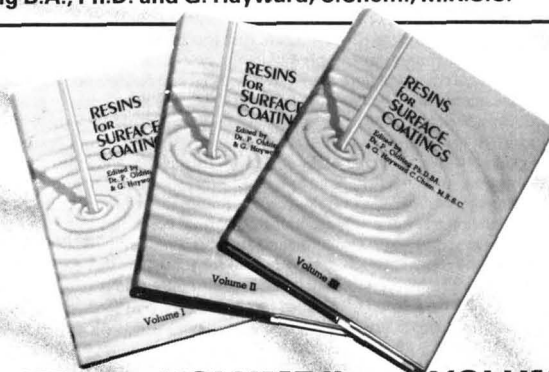
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Requirements of coatings

P. C. Robery BSc PhD CEng MICE, Taywood Engineering Ltd, 345 Ruislip Rd, Southall, Middlesex UB1 2QX, UK

1. Introduction

For the majority of applications, reinforced concrete can be used with confidence to build complex structures which will have a long, low-maintenance life. However, even with the latest design codes, the life of the structure will ultimately depend upon the care taken during the design and construction.

With poor detailing and insufficient site control over the four Cs (cover, cement content, compaction and curing), even the most prestigious structures will fail to meet their design lives. In such situations, protective coatings can be used to compensate for inadequacies at the time of construction.

Coatings may also form part of the original construction specification. In particularly severe exposure conditions design codes may underestimate the durability requirements for reinforced or prestressed concrete.

In both of these examples, barrier coatings can be used as an extra equivalent thickness of high quality cover concrete to protect the embedded steel. The requirements for these two applications, namely, corrective and protective systems, are:

- Barrier Properties
- Ease of Application
- Durability
- Cost
- Quality Control

A summary of requirements is listed in Table 1, with explanations given below.

2. Barrier properties

Protective coating systems for concrete are required to fulfil one of two functions:

- Protect the cement paste matrix against disruptive agents, such as sulphates or acids,
- prevent the ingress of deleterious materials which will result in corrosion of embedded steel, such as chlorides or carbon dioxide.

The particular barrier properties for

each situation are summarised in Table 2 and are discussed below.

Table 1
Summary of requirements

Barrier Properties

- Zero ionic diffusion (Cl^- , SO_3^{2-}).
- Acid resistance.
- Low CO_2 diffusion ($R \geq 50m$).
- High water vapour diffusion ($S_D \leq 4m$).
- Maintained property after 2000h UV.
- Zero water permeability.

Ease of application

- Tolerant to poor surface preparation.
- Suitable for application to damp concrete.
- Unaffected by high humidity and low temperature during cure.
- Resistant to high alkalinity.
- Simple to apply.
- Low toxicity/flammability/odour.

Durability

- Detailed case histories of 10 years or longer.
- Long-term crack-spanning performance.
- Unaffected by sunlight, freeze/thaw, immersion, or other service conditions.
- Long-term adhesion to concrete.

Cost

- Initial unit cost at the specified thickness.
- Preparation/application/access costs.
- Time between recoating intervals.
- Preparation/application/access for recoating.

Quality control

- Wet or dry film thickness measurements on site.
- Test cores to confirm barrier properties are satisfactory.

Ionic attack

With the exception of gaseous carbon dioxide, which is treated separately, the main aggressive agents to concrete are water borne. Barrier coatings for concrete, therefore, do not have to be of the highest protective category available; preventing access to water vapour or oxygen would be a more formidable task. The coating need only be impermeable to water under service conditions, such as driving rain or hydrostatic head (e.g. below ground-water or sea levels). With this criterion achieved, the diffusion rates for aggressive ionic species (Cl^- , SO_3^{2-}) will be zero, as can be confirmed by laboratory testing (Figure 1).

For acid exposure, an additional criterion is that the coating should not be softened or dissolved during service. Depending upon the type and strength of acid, this requirement may necessitate the use of higher performance coating systems than those used to prevent chloride or sulphate ingress.

Having a high water vapour transmission rate, in addition to impermeability to liquid-phase water, is a positive advantage for concrete coatings, allowing damp porous concrete to dry without risk of bond failure of the coating. Recently published figures recommend a minimum acceptable vapour transmission rate for concrete coatings¹. The figure is based on the rate of flux for water vapour from the centre of a saturated block of average quality concrete, namely $12.6 \text{ g.m}^{-2} \cdot 24 \text{ h}^{-1}$; this being equivalent to a 100mm thick concrete slice with a water vapour diffusion coefficient of $6.3 \times 10^{-3} \text{ cm}^2/\text{sec}$. Any coating system should have a flux at least equal to this figure, such that it offers no resistance to the movement of water vapour from within concrete. To simplify units, this water vapour transmission rate has been re-defined as an equivalent air layer thickness (S_D) as follows²:

$$S_D = \frac{d_{a,w} \cdot t}{d_{c,w}}$$

where $d_{a,w}$ = diffusion coefficient for water vapour through air (cm^2/sec)

$d_{c,w}$ = diffusion coefficient for water vapour through the coating system (cm^2/sec)

t = dry film thickness (m)

For concrete coatings, it is generally accepted that S_D should not exceed 4.0m.

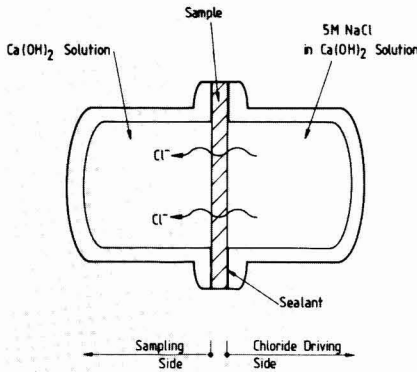
It should be noted that coatings designed to be resistant to acid attack or

Table 2
Requirements of coatings for different exposure conditions

Property	Ground Sulphates	Coastal Chloride	Industrial Acid	Industrial Carbonation
Zero Ionic Diffusion	E	E	E	N
Vapour Permeable	N	P	N	E
Acid Resistant	P	N	E	N
U.V. Resistant	N	E	P	E
Low CO ₂ Passage	N	P	N	E
Resist Pressurised Water	E	E	P	N
Typical Examples of Coating	Bitumens, Coat-Tar Epoxy	Epoxy, Polyurethane	Epoxy, Polyester	Acrylic, Alkyd, Cementitious

E = Essential, P = Preferred and N = Required.

Figure 1
TEL ionic diffusion cell



high hydrostatic pressures, will probably not satisfy the $S_D > 4m$ requirement.

Gaseous attack

Anti-carbonation coatings for concrete are designed to reduce the rate of ingress of atmospheric carbon dioxide to "acceptable" levels, rather than eliminate it entirely. The definition of an acceptable level will vary, depending on the structure to be treated. For example, a region of a new concrete structure with a low (say 15mm) cover, could be coated to prevent the depth of carbonation reaching the reinforcing bar within the design life of say 60 years. Whereas, in a repair situation, progression of the carbonation front may need to be restricted to less than 1mm for the remaining life.

For most circumstances, it is sufficient to define a single performance criterion for coatings which are to reduce the ingress of carbon dioxide: the coating should provide a resistance to carbon dioxide diffusion which is at

least five times better than 25mm of average quality concrete (i.e. $>125mm$ equivalent thickness of concrete). This will be satisfied by coatings with an R-value of not less than 50m, defined as follows:

$$R = k_{cc} \cdot t \quad (m)$$

$$d_{cc}$$

where d_{cc} = diffusion coefficient for carbon dioxide through the coating (cm^2/sec)

$$t_{cc} = \text{dry film thickness (m)}$$

k_{cc} = constant - diffusion coefficient for carbon dioxide through air (cm^2/sec).

It has been shown that an R-value of 50m will effectively halt further carbonation³, producing less than 2mm movement of the carbonation front in 50 years (Figure 2). Again, a high vapour transmission rate is required, with S_D not greater than 4.0m.

Weathering

The above performance criteria for ionic and gaseous barrier coatings

assumes that the properties at the time of application are maintained throughout the life of the structure. This will not be true unless a programme of planned maintenance (re-coating) is carried out. At the very least, the coatings would be expected to maintain their properties for five years.

As a guide to performance in service, artificial weathering can be used to accelerate degradation of protective coatings⁴. Recently, it has been shown that some coatings can rapidly reduce in R-value when subjected to fluorescent-type ultraviolet light; after only 500 hours, one coating reduced in protection by over 8 fold. As a minimum, therefore, protective coatings for concrete should be tested to determine their resistance to ionic or gaseous diffusion after artificial weathering to 2,000 hours UV exposure. This is commonly believed to be equivalent to approximately 5 years natural exposure in average UK external conditions. This will demonstrate that the two variables comprising the R-value (t and d_{cc}) remain at satisfactory levels for the $R < 50m$ criterion to be satisfied.

Other durability-related requirements are discussed below.

3. Ease of application

Coating systems have to be specially formulated to be compatible with the damp, alkaline, voided concrete surface. Also, they must be suitable for application using the simplest techniques, taking due account of the fact that buildings may be occupied during painting operations (i.e. offer a low odour/toxicity/flammability risk). These points are developed below.

The substrate

The porous nature of the cement paste, which binds the aggregate of concrete mixes together, is largely unappreciated by engineers and paint formulators alike. A well-cured, low water content paste ($W/C = 0.47$) will have a porosity of approximately 40% by volume, equivalent to 12% porosity in a concrete mix; for a poor quality concrete, this figure could rise to over 30%. The pores form a network of inter-connected tubes, or "capillary voids", within the concrete.

The diameters of the capillary voids are in the range 0.05-2 μm , making them invisible to the naked eye (Figure 3). These are quite separate from the visible trapped air pockets seen on the concrete surface (0.5-5mm in diameter) which contribute only 0.5-1% to the voidage in concrete. By nature of their size, capillary voids will fill or empty with water in response to variations in

Figure 2
Effect of R-value on concrete carbonation

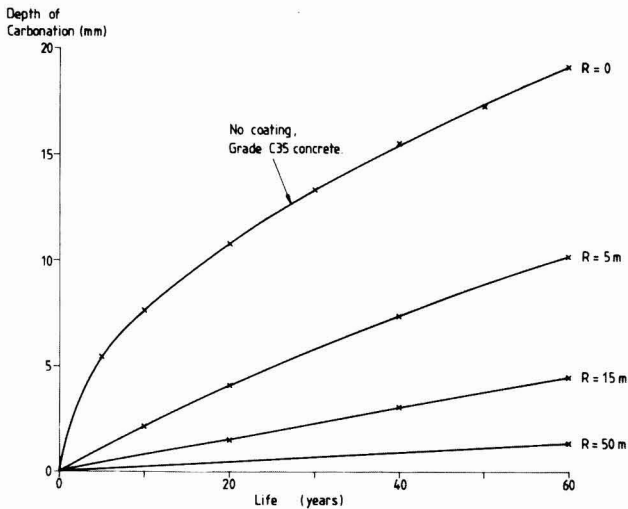
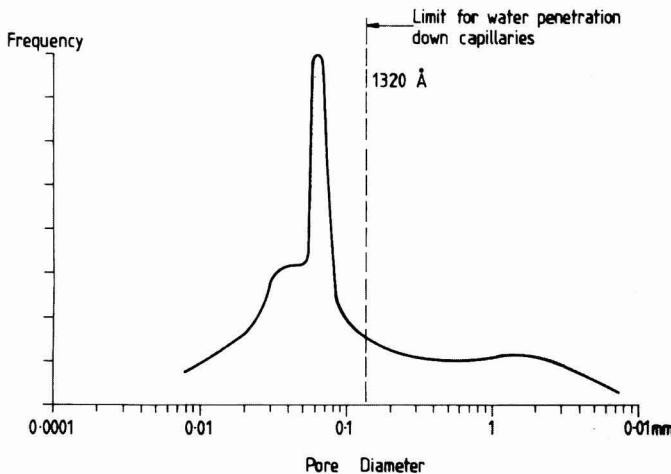


Figure 3
Typical capillary pore size distribution



atmospheric humidity, although this may take several months to achieve. This uptake will be accompanied by swelling or shrinkage of the cement paste respectively — concrete is almost alive.

Finally, the concrete surface itself will be dusty and contaminated with formwork release agents such as

mineral oils, stearates or waxes. There may also be a weak layer present on the surface if the concrete was cast as a slab (laitance). The surface may also be fissured by two types of crack: passive (not moving) shrinkage cracks formed during the first few hours or weeks after casting, with a width ranging from hairline to several millimetres; and

active structural cracks, cycling between hairline and typically 0.3mm in width.

The paint system

The successful performance of the system will depend upon the care taken in the selection of the components, with the choice based on relevant test data. The satisfactory performance of paints on steel or other surfaces is no assurance that the system will work on a concrete substrate. The complete coating system will comprise of four stages:

- preparation of the concrete surface,
- compounds for filling passive cracks and voids,
- penetrating primer, compatible with the concrete,
- protective layer(s), capable of flexing over active cracks if necessary.

Above all else, the paint system should fall firmly into one of two categories; either to be applied by specialist applicators only, or to be simple to use by non-specialist construction personnel. The latter is probably the most common category and the one producing the most problems due to mis-use. For this category in particular, the components of the paint system should be simple to mix and apply and be tolerant to damp concrete and unfavourable weather conditions. Finally, the paint should be "user-friendly", preferably requiring nominal health and safety precautions for the applicator and occupants in surrounding buildings.

4. Durability

Laboratory testing of a coating system using accelerated weathering techniques can be used to demonstrate that its barrier performance is satisfactory for the intended application⁴. However, in other respects, such as resistance to freeze/thaw cycles or embrittlement with age, methods of test have not yet been standardised.

In the absence of universally accepted test regimes, the specifier has to rely upon the proven durability of a paint system in similar exposure environments. Currently, such case studies form merely a list of contracts, with no documented information on weathering performance in service.

To assist the specifier, illustrated case histories are required. Such studies would show whether the coating can satisfactorily bridge over cracks and defects in the concrete over say a 10-year period. Also, supported by information on the moisture content of the concrete at the time of application, the resistance to freeze/thaw cycles and daily temperature fluctuations can be demonstrated.

This type of detailed information is not readily available.

5. Cost

The total cost for a coating system cannot be judged as the unit cost for the first application. This would ignore the cycle of re-coating, with its associated preparation, access and application costs. The fact is that the first brush-stroke of paint commits the owner to the regular expense of re-coating his building; this is often not highlighted by the coating applicator or supplier.

The total cost will include the following items:

- initial paint costs and dry film thickness,
- special application requirements,
- time to re-coating, for either aesthetic or protective reasons,
- preparation before re-coating,
- ease of re-coating.

The lowest cost option will most commonly be the paint with the longest time to first maintenance. Paints, therefore, should have low dirt pick-up characteristics or be coloured in such a way as to weather un-noticed. Perhaps there is a market for "designer grime" on the colour cards.

Certainly, the specifier needs all the above information before a proper cost vs performance comparison can be prepared for the different coating systems.

6. Quality control

The final requirement of coating systems is the ability to check whether the coating has been applied correctly. As discussed above, the barrier performance of a coating depends upon both its inherent resistance to diffusion (ionic or gaseous) and its dry film thickness. Under-application of a coating system will significantly reduce the level of protection that can be achieved.

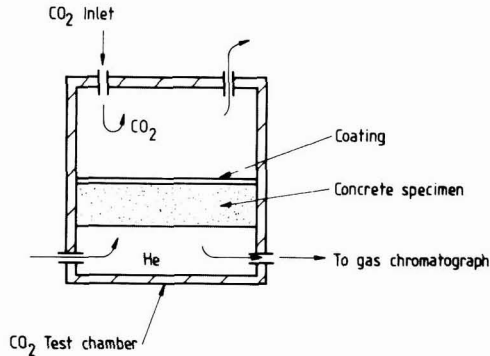
Because concrete surfaces are inherently rough and uneven, it is difficult to measure wet film thicknesses directly by use of comb or wheel gauges. Once applied to the concrete, the dry film thickness can only be measured by destructive means, such as by paint borer or using a microscope on cored samples (e.g. bond test areas). Currently, the only means for ensuring that a uniform film thickness is achieved, is by metering the quantity of paint applied per square metre of concrete; this is far from satisfactory.

Continuity checks can be made by utilising the conductive reinforcement in the concrete. Completing the circuit via a wet sponge placed on the coating surface will give a resistance reading which falls rapidly over pinhole defects.

The barrier performance of the applied coating can be checked destructively, by taking 100mm diameter core samples from the coated concrete surface. The ionic, or gas

Figure 4

TEL test rig for the measurement of gas diffusion through coated concrete



diffusion properties can then be measured and compared with the supplier's data (Figure 4). Also, the acid resistance of the sample can be checked, using acid ponding tests for example.

7. Conclusions

Protective coatings for concrete can only be specified with confidence if a complete understanding of the performance requirements is obtained. This requires the paint formulators to provide performance data on their coating systems, relevant to the behaviour on concrete. There are several areas where additional information could be provided or further tests undertaken:

- 1) Test data for barrier properties, relevant to ionic, acid or gaseous ingress when applied to concrete substrates.
- 2) Maintenance of barrier properties after weathering.
- 3) Development of easy to use, high performance, low and high-build water-based paints, which have no toxicity, flammability or odour problems and are single component.
- 4) Detailed, illustrated case histories for paint systems, demonstrating the system is durable under UK conditions; test data for cores taken from old coated structures would provide invaluable data on the long-term barrier resistance characteristics.
- 5) Accurate information on the time to re-coating, based on either aesthetic needs or the reduction in barrier properties with natural weathering.
- 6) Recommended quality control procedures for ensuring the required protection is achieved in service.

Following close discussion between

testing organisations and coating companies, it is to be hoped that new test methods and standards can be produced which provide information on the above six points.

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Polymer emulsion based systems for the protection and repair of concrete

by P. B. Jones, Harlow Chemical Company Ltd, Templefields, Harlow, Essex CM20 2AH, UK

The desirability of the widespread painting of concrete remains controversial. Besides the off-putting question of maintenance, many classes of coating are prone to poor adhesion on densified concrete and there are specific problems in painting green concrete. There is however an obvious need to protect concrete in high risk situations and in this paper the performance of thermoplastic polymer emulsion based systems will be discussed.

The market for concrete coatings can broadly be divided into protection and repair, although the same products may be suitable for both applications.

Concrete repair

In restoration, the coating may be applied to both conceal and protect the repair and surrounding area. Since the repair materials and concrete itself represent quite different substrates, an appreciation of their nature is important, the substrate being highly influential in determining coating performance.

Turning first to the repair of spalled concrete, correct diagnosis of the causes and extent of corrosion damage is fundamental to the success of repair procedures. Where corrosion of the steel re-inforcing bar has occurred causing cracking and spalling, the concrete cover should be cut back behind the bar to allow effective cleaning, preferably by grit blasting. It is also important to cut back at each end of the bar where sound concrete still exists until no more corrosion is found.

It is generally recommended that a protective metal primer be applied to the rebar and among the favoured systems used are two pack solvent free epoxies. There has been debate on whether and how to coat the rebar. Concern has been expressed that altering the nature of the surface of the rebar around the repair area may set up an electrochemical reaction at another point along the bar, leading to further

corrosion. Polymer modified cement applied as a thin slurry can produce a very gas impermeable layer with excellent adhesion to steel.

There are, of course, a number of alternative systems available for the repair of concrete¹. Where the depth of cover is from 12-25 mm, a polymer mortar should be used, the installation of the mortar is preceded by the application of a bonding aid to ensure adequate adhesion. An acrylic emulsion mixed with sand and cement at a ratio of one part of cement to 0.25 parts of polymer to 2 parts of sand is recommended. The mortar infill should be applied while the primer is still wet for best results. The mortar should be formulated to exhibit minimal drying shrinkage. The aggregate size in the mortar should not exceed 3 mm and a water/cement ratio of 0.35 or less should be used to minimise porosity and maximise strength.

The next stage should be to restore the surface of the repair and surrounding area to a uniformity to accept the anti-carbonation coating. Inevitably there will be cracks and defects in the surface which require filling and a levelling compound can be used for small defects. Larger ones, greater than 15 mm, should include some cement.

Optionally, a penetrating solvent borne stabilising system may be applied to bind down any friable material and seal the surface. Alternatively a fine particle size emulsion based system may be used to eliminate variable suction in the surface. Finally the protective coating is applied, where this is an emulsion paint, two coats should be applied to eliminate defects and afford a more even coverage. A more detailed description of the system described above, together with formulations for the components, has been provided by Sellars².

When characterising protective coatings, the under primer should always be considered since it will be part of a composite layer providing

protection. The advantage of using a water-borne primer is that it provides a coating having a surface free energy compatible with an emulsion based topcoat.

A study by Mondt³, has demonstrated the excellent penetrating properties of a polymer emulsion having a mean particle diameter of 0.05 microns. Using a fluorescence technique, he was able to measure the depth of penetration of the emulsion particles into various hydraulically bound surfaces.

Polymer modified mortar

Before covering the selection and performance of topcoats, the nature of polymer modified mortar will be considered, since it is often a combination of this repair material and concrete which an applied coating has to protect.

Emulsion polymers are added to cement to improve adhesion, reduce permeability, increase flexural and tensile strength, reduce shrinkage and aid workability, amongst other properties.

When polymer emulsions are mixed with fresh cement mortar, the polymer particles are uniformly dispersed in the cement paste phase. As the cement gel is gradually formed by the hydration reaction and the water phase is saturated with calcium hydroxide formed in the reaction, the polymer particles deposit partially on the surface of the cement particles. With drainage due to the development of the cement gel structure, the polymer particles are gradually confined in the capillary pores. As the hydration reactions proceed further, the capillary water is reduced and the polymer particles flocculate to form a continuous layer of close packed particles (Figure 1). Finally as the water is withdrawn the close packed polymer particles coalesce and bind the cement hydrates together to give a monolithic network⁴.

Surfactants are essential components of emulsion polymers and care must be taken to ensure they do not entrain

Figure 1

Polymer emulsion particles deposit on the surface of the cement gel (grey tint) and aggregate (////) as the capillary water is withdrawn.

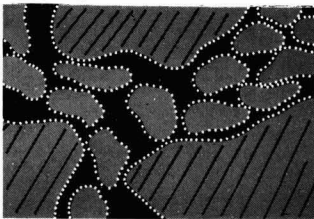
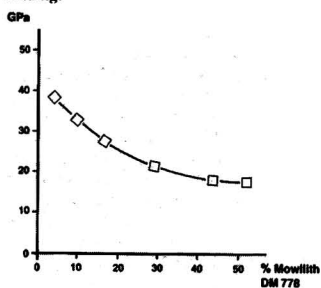


Figure 2

Elastic modulus as a function of polymer loading.



excessive air. A properly compounded emulsion with plasticiser and defoamer will ensure minimum air entrapment, unfortunately such products are not always used.

In a well formulated repair mortar, the gas permeability can be many times less than that of the surrounding concrete.

Figure 2 shows the influence of polymer level on elastic modulus. In repair situations, it is usually desirable to have an elastic modulus of the repair material less than that of the surrounding concrete. The magnitude of elastic modulus can be controlled by level of polymer addition. Typically in repair mortars, the level of polymer modification is around 25 per cent by weight of cement.

Protective role of coatings

The main performance requirements of coatings for concrete are that they resist the passage of water, possess a finite water vapour permeability, are flexible, exhibit good adhesion, are resistant to alkalis, restrict the passage of carbon dioxide and are durable. Considerable attention is often paid to characterising the gas transport properties of coatings for concrete with less concern for other factors. In particular, it is generally necessary to arrive at a compromise of properties to get the best all round performance, particularly with respect to durability.

Factors influencing gas transport properties

Hoechst have developed their own method for measuring the diffusion rates of carbon dioxide and sulphur dioxide through coatings⁵. The results quoted in this section were obtained on this equipment. The method involves analysing a carrier gas stream swept over the coating applied to calciferous sandstone or carton board, suitably preconditioned, through which the test

gas is diffusing. The gas is fed to a gas chromatograph fitted with a thermal conductivity detector by pre-calibrated metering loop. The relationship between the measured flow rate and the diffusion resistance coefficient is given in Equation 1.

$$\mu = \frac{DL \cdot C}{J_s \cdot S} \quad [1]$$

where

- μ = diffusion resistance coefficient
- DL = diffusion coefficient for CO₂ in air (m².sec⁻¹)
- C = concentration gradient (Kg.m⁻³)
- J_s = measured diffusion rate (Kg.m⁻².sec⁻¹)
- S = film thickness (m)

The diffusion resistance coefficient μ is a useful parameter in that it indicates how permeable a coating is to a gas compared to an equally thick layer of air. The air diffusion equivalent values R (for CO₂) and S_D (for water vapour) are more commonly quoted and these are calculated from the μ values by Equations 2 and 3 respectively.

$$R = \mu \text{CO}_2 \cdot S \quad [2]$$

$$S_D = \mu \text{H}_2\text{O} \cdot S \quad [3]$$

According to Klopfer the R value should not be less than 50 metres⁶.

In the results quoted, water vapour permeability measurements were made by the wet cup method according to DIN 52615. Ideally the S_D value should be less than the measured value for 25 mm of concrete cover (2m). It is important that the air diffusion equivalent values for CO₂ are maintained above 50m for the effective life of coatings and there is only limited experimental data available to show how they change on weathering⁷. A margin of safety is therefore advisable.

Table 1 compares different types of emulsion polymer binder as formulated into 50% pigment volume concentration (PVC) paints. It can be

seen that the R values for all the paints significantly exceed the defined limit of 50m. Published data shows that most integral pigmented systems easily exceed this value. Noteworthy is the high CO₂ diffusion resistance coefficient of the solution acrylic binder but the equivalent value for water vapour approaches the value for 25 mm of concrete. The low film thickness of this class of product is also typical.

The vinyl acetate/ethylene/vinyl chloride terpolymers yield paints with very low carbon dioxide permeabilities. Acrylic emulsion paints give good all round results and have the highest water vapour permeabilities. The advantages of thick water borne coatings can also be appreciated from these results where it is possible to have much thicker films with correspondingly high R values.

A study of the influence of the nature and level of pigmentation on gas permeability has also been undertaken. It was found that for a vinyl acetate/VeoVa10 copolymer bound emulsion paint, the carbon dioxide diffusion resistance rises to a maximum just below the critical PVC (Figure 3). Similar trends have been observed with other binder types. To appreciate the significance of the graph, it should be understood that properties of paint films are largely governed by pigment volume effects. As the pigment volume is increased, the critical point is reached when there is just sufficient volume

Figure 3

CO₂ permeability of a VA/VeoVa 10 bound emulsion paint as a function of PVC

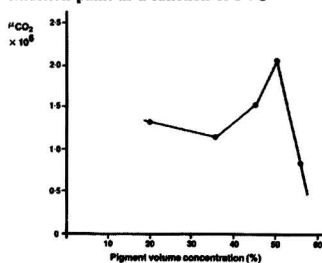


Table 1

Diffusion of CO₂ and H₂O vapour data for 50% PVC paints

Paint Binder	Dry Film thickness (mm)	μCO_2	R _{CO₂} (m)	$\mu \text{H}_2\text{O}$	S _{H₂O} (m)
VA/Et/VC Terpolymer Emulsion	0.15	5×10^6	750	6×10^3	0.9
Pure Acrylic Copolymer Emulsion	0.15	2×10^6	300	3×10^3	0.5
Styrene/Acrylic Ester Copolymer Emulsion	0.15	1×10^6	150	5×10^3	0.8
Solvent Borne Acrylic Concrete	0.07	8×10^6	560	3×10^4	2.0
	25	300	7.5	1×10^2	2.5

fraction of the binder to constitute a truly continuous phase, the significance of the CPVC is that many of the properties of the paint, including permeability, change abruptly at this point. It is evident from Figure 3 that the sharp fall in diffusion resistance coefficient comes about because the CPVC has been exceeded. It would appear beneficial to formulate anti-carbonation coatings as close to the CPVC as practicable.

Factors such as composition of the binder, mean particle size and distribution of sizes and nature of aqueous phase of emulsion polymers determine CPVC as does the nature of the pigmentary system. One way to compare the performance of alternative systems is to use the reduced PVC concept as described by Bierwagen and Hay⁸. These authors defined the reduced PVC of a paint as being the ratio of the actual PVC to the CPVC. By plotting graphs of film property versus reduced PVC, one can superimpose plots for different systems and make a fair comparison. Due to the amount of practical work involved, the CPVC is rarely determined for paint systems and without this knowledge, it is difficult to draw conclusions.

Desor and Pauly⁹ have also investigated the influence extender type plays in influencing permeability. Their results show that lamellar types give superior resistance to carbon dioxide diffusion compared to rounded extenders.

Formulation considerations

The manner in which emulsion paint formulation parameters can influence film properties will now be considered.

The emulsion polymer binder, both in terms of composition and proportion present will determine the thermoplasticity of the film. Binders are generally chosen for exterior use in terms of their chemical resistance and photostability. They comprise copolymers and terpolymers, the constituent monomers being adjusted to provide coatings with the required balance of hardness to resist dirt pick-up and flexibility to cope with substrate movement without cracking. In this respect pure acrylic copolymers are advantageous in that paint films have less temperature dependent mechanical properties than many other classes of binder.

The choice of pigmentary system is very important since inorganic minerals can influence durability in different ways. Factors such as binder demand, particle shape, chemical reactivity and photostability must all be considered. Lamellar extenders like talc and mica are chemically inert, provide re-

inforcement to the paint film and optimise the spacing of titanium dioxide particles. Lower cost extenders such as calcite, silica and dolomite often have low binder demand, good colour and can be incorporated at reasonable levels in paint formulations without adversely affecting rheology. Highly durable paints can be formulated at PVCs close to the critical level¹⁰. In this respect there is a parallel between optimum gas transport properties and durability.

The thickener system should be selected so as to provide the paint with a rheology to enable rough surfaces to be covered evenly. Water soluble polymers however contribute to the hydrosensitivity of films.

Coalescing solvent is an essential component. It has been shown that there is an optimum level of coalescing solvent for any particular formulation to achieve a well compacted film with minimum internal stress¹¹. It has also been shown that the level of coalescing solvent influences water vapour permeability. Coalescing solvent can remain in a film for many months after application and this is a point to be borne in mind when characterising coatings.

The influence of minor components such as dispersant, biocide and defoamer should not be overlooked since each of these can influence film properties in its own way.

Durability considerations

Exposure to the elements can bring about significant changes in film properties of exterior paints. The first few wetting/drying cycles due to rainfall will leach out some of the water soluble components and also cause expansion (swelling) and contraction of the film, severely testing adhesion.

Exposure to ultraviolet light can give rise to the phenomenon of chalking and to embrittlement of films. In a study to investigate the effects of exposure to ultraviolet radiation on the mechanical properties of emulsion paint films, it was found that tensile strength increased and elongation decreased to start with. After a period, the tensile strength decreased probably indicative of degradation of the binder¹⁰.

Any incompatibility in systems (i.e. between topcoat and primer or substrate) can quickly become evident on natural weathering particularly where the system experiences rapidly changing temperatures.

Conclusion

Water based coatings can be applied at reasonable thicknesses as paints or renders and achieve extremely low

carbon dioxide permeabilities whilst being permeable to water vapour.

For good gas transport properties, binder type is not critical as long as it has the required balance of hardness and flexibility to resist dirt pick-up and cope with substrate movement. The all-round balance of properties conferred by an acrylic emulsion binder is beneficial. To optimise properties, the paint should contain lamellar extender and be formulated close to the critical PVC.

Thick water borne renders provide a good option and there are several commercial systems available supported by fairly impressive performance data. Such systems are particularly good at bridging cracks and concealing repair.

Emulsion paint films undergo many changes in their early life and drawing conclusions from laboratory measurement without due consideration can be misleading.

In conclusion, there is no substitute for site experience and there is much convincing evidence to support the use of correctly formulated and applied emulsion based systems.

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Based on Paper presented at the OCCA Thames Valley Section Symposium "Durable and Protective Coatings for Concrete", 4 July 1988, Heathrow, London.

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See Page 395**

Concrete protection with methacrylate resins

by E. Sattler, Rohm GmbH Chemische Fabrik, Postfach 4242, 6100 Darmstadt 1, West Germany

Over the last ten years an ever increasing number of buildings has been in need of partial or complete repair of the damaged concrete surfaces. The causes are design faults, inferior concrete quality, inadequate coverage of the steel reinforcement, change in usage and an increasing environmental pollution, but never the material concrete itself.

Some of the available materials for concrete protection and concrete repair have been discussed in a very subjective and contradictory manner. Before referring to this a few comments first on concrete corrosion.

According to Klopfer, the major cause of corrosion is the carbonisation of the concrete, which is the formation of calcium carbonate by the reaction of carbon dioxide with the calcium hydroxide contained in the concrete.

It has been found that the concrete not only carbonisates under the influence of gaseous carbon dioxide from the atmosphere but may also be severely damaged by carbon dioxide-containing water, especially if it is porous. The dissolution of carbon dioxide in water results in the formation of carbonic acid ($H_2O + CO_2 = H_2CO_3$). If concrete is permanently exposed to water containing carbonic acid, the reaction is as follows:

Calcium carbonate plus carbonic acid gives calcium hydrogen carbonate: $CaCO_3 + H_2CO_3 = Ca(HCO_3)_2$. Contrary to calcium carbonate, calcium hydrogen carbonate is an easily soluble compound.

On prolonged exposure to rainwater containing carbonic acid, the calcium carbonate formed in the pores of the concrete is thus dissolved and transported to the surface. The pores are thus open again, and this promotes carbonisation. On the other hand, however, calcium hydrogen carbonate is not a stable compound. Upon evaporation of the water it dissociates into calcium carbonate, and carbon dioxide is set free. The cycle starts anew.

For the above reasons a protective layer applied to concrete as a carbonisation barrier must not only be tight against diffusing, gaseous CO_2 but also sufficiently weather-resistant and highly watertight.

The question of which coating material is the most suitable for repairing damaged concrete surfaces or to act as a carbonisation barrier has been discussed with vehemence in recent times. Yet it is clearly answered by a research report which the Technical University of Braunschweig, Institute for Building Materials, Solid Construction and Fire Protection (authors K. Kordina, J. Neisecke), prepared at the request of the Federal Ministry of Architecture, Area and Town Planning. This report analyses different coating materials not only for their protective action against concrete corrosion but also and in particular for their durability. Silicone resins, for example, silanes and siloxanes are waterproofing agents which make the concrete surface water-repellent but do not affect the water vapour permeability. Even though problems like alkali resistance and an increased soiling tendency are now solved, the use of these products on concrete still poses certain problems. As a result of the drier surface, the concrete becomes more highly permeable to gas, so that the carbonisation may be more pronounced than in the case of non-waterproofed concrete. According to the present-day technical experience, aqueous coating materials – due to their open pores and/or often inadequate weather resistance – are unable to afford sufficient protection.

For a number of years paints on a methacrylate resin base (Figure 1) have been widely used in the most different formulation for building applications.

Depending on the resin content, pigmentation and other additives, these

are either colourless, visually hardly perceptible impregnations or coloured hiding coatings.

Coatings on a methacrylate resin base are sufficiently watertight and offer the advantage of being adequately water vapour permeable (about 15,000 μH_2O) and provide a remarkably good carbonisation barrier (about 2 million μCO_2) at the same time. According to our present knowledge a thoroughly dried double-layer coating of methacrylate resin (layer thickness about 100 μm) shows a diffusion resistance to water vapour $W H_2O$ of 1.5 m (corresponding to about 3-4 cm of concrete) and a diffusion resistance to $CO_2 - W CO_2$ – of about 200 m (corresponding to about 50 cm of concrete). This satisfies well the demands for an effective carbonisation barrier.

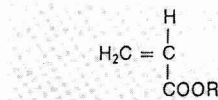
These methacrylate resins are mainly copolymers on the basis of n-butyl methacrylate, isobutyl methacrylate and methylmethacrylate (Figure 2). Compared to other coating materials, methacrylate resin paints have the following advantageous properties:

- UV-resistant
- colourfast
- non-yellowing
- do not become brittle
- are largely stress-free
- waterfast
- alkali – and acid – resistant
- water vapour-permeable
- carbon dioxide tight.

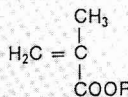
The sum of these properties is unrivalled and sets methacrylate resins apart from all other paint binders. It is also worth emphasising that the UV-resistance of methacrylates cannot be achieved with any other system (Figure 3). This results in an outstandingly high weather resistance that is also known for [®]PLEXIGLAS, a polymethyl methacrylate. The oldest known protected objects with a methacrylate based coating date from 1960 to 1967 and are still perfectly intact. It should be noted that the high protective effect of methacrylates is first achieved at a layer thickness of only about 100 μm . This ensures that the texture of the concrete surface is not affected in any way and remains visible. Moreover, as a result of the described properties it is possible to permanently protect concrete with a thin-methacrylate coating in cases where the steel coverage has been inadequate from the start.

In view of the extensive concrete repair work that is required currently the question is posed at regular intervals whether a concrete structure should, as a matter of principle, be provided with a protective coating immediately upon completion. If the specifications in terms of concrete composition, filling

Figure 1



acrylates



and methacrylates

R = CH_3 (methyl), C_2H_5 (ethyl) etc.

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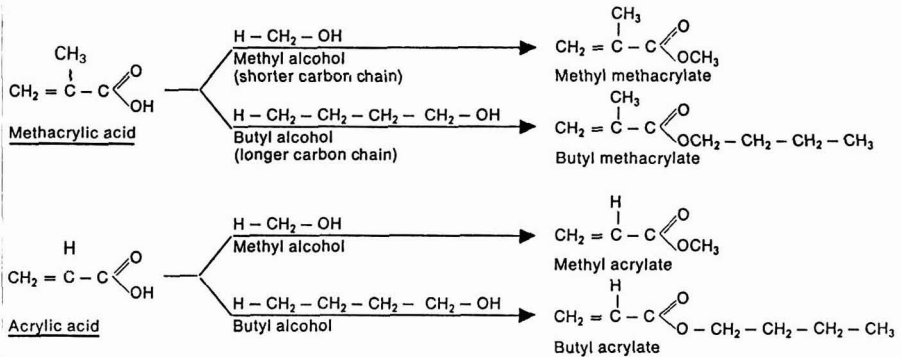
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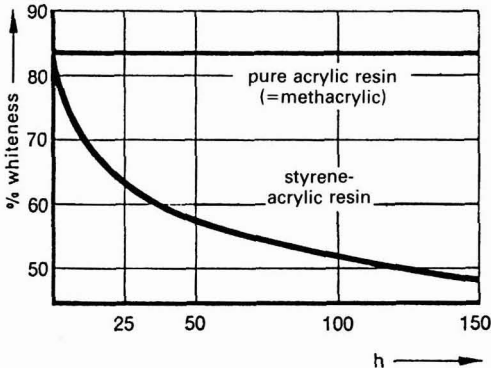
Figure 2



The acids and alcohols used for making the monomeric ester produce the following effects:
Methacrylic acid – leads to harder films, has little effect on aliphatic solvent solubility
Acrylic acid – reproduces softer films, also has little effect on aliphatic solvent solubility
Short-chain alcohols – lead to harder films and insolubility in aliphatic solvents
Long-chain alcohols – yield softer films and impart solubility in aliphatic solvents

Figure 3

Tendency to yellowing of masonry paints on exposure to UV radiation.



in, compacting and post-treatment are duly observed, and given adequate concrete coverage of the reinforcing steel, such concrete structures are permanently weather-resistant even without a protective coating.

Yet, if the soiling tendency is very pronounced and the layers close to the surface are distinctly porous, a methacrylate coating may improve the aesthetic appeal and ensure a satisfying appearance for many years. In the case of defective decorative concrete façades, however, inadequate steel coverage as a result of poor workmanship or above-average chemical attack, protective coatings on a methacrylate base are absolutely indispensable.

If a careful selection is made from the available system which is skilfully applied and chemical as well as physical aspects duly observed, defective concrete surfaces can nowadays be perfectly repaired and permanently protected against corrosion with suitable coating systems on a methacrylate base. Long-term practical experience has shown that a concrete which is protected in good time will not be in need of costly repairs at a later stage. ■

Based on Paper presented at the OCCA Thames Valley Section Symposium "Durable and Protective Coatings for Concrete", 4 July 1988, Heathrow, London.

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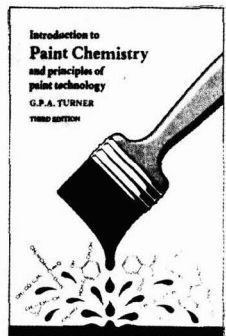
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Two-pack acrylic urethane systems

by K. O'Hara, Cray Valley Products Ltd, Farnborough, Kent BR6 7EA, UK

Introduction

Two pack acrylic isocyanate systems were developed in the 1960s and have since found extensive use in a number of segments of the industrial coatings market. The main areas where these are used commercially are in:

- Vehicle refinishing
- Transport finishing
- Coatings for plastics
- High quality general industrial
- Wood coatings
- Masonry coatings

Although today acrylic urethanes have found limited use in the coating of concrete some of the basic properties which have made them an attractive option in other fields also make them worthy of serious consideration for the protection and decoration of concrete.

Current applications for acrylic isocyanate systems applied to cementitious substrates include:

1. Concrete floor coatings applied both as a two coat system directly to concrete and also as the topcoat over an epoxy primer.
2. The exceptional resistance properties of the cured film lend this system to use in clear and pigmented anti-graffiti coatings on concrete, masonry and other surfaces.
3. A clear sealer applied to paving slabs helps to keep the surface clean, reducing growth of algae and efflorescence.

Acrylic urethane systems have the following general characteristics:

- Durability
- High chemical resistance
- Good cure properties
- Colour stability
- Build

Through judicious monomer choice and the control of other parameters such as hydroxyl level, molecular weight and molecular weight distribution the resin formulated can produce a wide selection of film properties, ranging from very hard, abrasion and stain resistant films to tough, elastic coatings, whilst at the same time retaining the central feature of the acrylic urethane crosslinked polymer network.

Acrylic urethane coatings are produced by combining a hydroxyl functional acrylic solution copolymer with an isocyanate adduct. The high

performance achieved by acrylic solution copolymers (thermoplastic and thermosetting) and emulsion copolymers is well known. They have excellent colour stability and resistance to UV. In addition the carbon-carbon nature of this polymer backbone is very resistant to chemical attack. In the case of two pack acrylic isocyanate systems this high performance is further enhanced by the presence of urethane crosslinking groups in the cured film. These groups help to produce tough, abrasion resistant film finishes and also make a positive contribution to chemical resistance and exterior durability.

It is recognised that high coating thickness is one of the most important means whereby ingress of chlorides and carbon dioxide can be reduced thus extending the life of concrete. Concrete and masonry coatings require much higher coating thicknesses than normal and at least 200 microns d.f.t. are necessary to provide adequate protection¹. It follows that the higher the solids of the coating the easier it is to achieve these film thicknesses. An important feature of chemically cured coatings is their ability to combine high performance with high application solids. Other solution coatings, e.g. chlorinated rubber, thermoplastic acrylics and others rely on molecular weight built into the original polymer to achieve performance. This is of course achieved at the expense of solids.

For an airless spray applied coating volume solids of typical systems are shown in Table 1.

Parameters affecting properties of acrylic urethanes

A. Acrylic copolymer

1. Functional monomer

The choice and level of hydroxy functional monomer primarily governs the amount of isocyanate adduct required to achieve stoichiometry which in turn affects the initial drying and also the final crosslinked density of the cured film. The higher the crosslink density the greater the "urethane" content of the film and the higher such properties as abrasion and chemical resistance of the film.

Hydroxyl level is expressed as % OH on polymer or hydroxy equivalent weight (the number of grams of solid polymer containing 17 grams of OH). Hydroxyl contents of acrylics can range from less than 1% to 6% but are typically 1.5% to 4.0% based on solid resin.

2. Backbone monomer

The choice of backbone monomer not only has a direct affect on the polymer glass transition temperature and therefore film flexibility, hardness, etc. but also on the overall weathering properties of the film. It is well known that high styrene levels produce hard brittle films with limited weathering potential. Methyl methacrylate contributes both durability and colour stability. Monomers such as ethyl and butyl acrylates are used to plasticise the

Table 1

Airless spray applied volume solids of typical systems

	Approx. volume solids (%)
High build 2-pack acrylic isocyanate	55
High build 2-pack epoxies	55+
Chlorinated rubber	30-35
Alkyd	50-55
Styrene acrylic thermoplastic	30
Acrylic latex	40-50

Table 2

Acrylic range	Approx. T _g (°C)	% OH	Wt. * solids @	Comments
Synocure 863SD	64	2.8	52	All round properties, good pigment wetting.
Synocure 865SD	30	3.1	61	High build, maximum durability.
Synocure 867SD	70	2.8	51	General purpose, good chemical and stain resistance.
Synocure 869SD	47	1.5	38	Fast dry, long pot life.
Synocure 871X	-10	3.6	54	High flexibility and extensibility. Tough, abrasion resistant, etc.
Synocure 872SD	25	4.0	50	Highest chemical and stain resistance combined with abrasion resistance.

* Adducted clear lacquer thinned to 2 poise at 25°C.

polymer backbone. A wide selection of other unsaturated monomers are commercially available, each offering their own particular combination of properties.

3. Molecular weight

Both molecular weight and molecular weight distribution play a vital part in polymer formulation since it affects not only the initial drying, cure rate and final film performance, but also application properties. Outside direct molecular weight determinations the most convenient way of characterising this property is through its viscosity/solids content relationship.

Cray Valley Products Ltd offer an extensive range of acrylics for two pack finishes and those deemed to be most suitable for masonry and concrete coatings are listed in Table 2.

As already stated all of these products are capable of producing films with excellent colour stability and long term durability and the life expectancy of a correctly applied coating system based on such products is well in excess of ten years.

B. Isocyanate adduct

Both aromatic based and aliphatic based adducts are available but for use with durable, colour stable polymers such as acrylics it is generally regarded as sensible to combine them with their colour stable counterparts, i.e. the aliphatic isocyanate adducts.

The adduct most commonly used in combination with acrylic polyols is the trifunctional biruet formed by the

condensation of three moles of hexamethylene diisocyanate (HMDI) and water. Bayer produce this product under the trade name of Desmodur N. Rhone Poulenc produce an equivalent (Tolonate HDB75).

The trimer of HMDI has also become available (Desmodur N3390 or Tolonate HDT90). This offers very similar properties to the Desmodur N type but with better solids and superior exterior durability².

Isophorone diisocyanate adducts are also available, e.g. T1890, and IPDI/TMP adduct available from Veba Chemie.

Bayer have recently introduced Desmodur 2877 which is a very flexible aliphatic adduct and may offer some advantages for flexible membranes.

Properties required of coatings for concrete

The most important properties required of a successful coating system for concrete are now discussed, with comments on how an acrylic urethane system can be expected to perform in these areas.

Application

Two pack acrylic urethanes may be applied by airless spray, brush or roller, and their high application solids enables a rapid build up of film thickness to be achieved. In order to maximise the protection afforded by a coating system more than one coat is necessary. The excellent recoatability properties of acrylic urethanes mean that application of the second coat is not critical in terms

of timing.

Drying and curing

Acrylic urethane systems can be successfully applied over a wide range of ambient conditions. This contrasts sharply with two pack epoxies where serious difficulties can be experienced at low temperatures. At 5°C or less the cure of most two pack epoxy systems is essentially non-existent. Similarly problems can occur with water based systems at low temperatures and under conditions of high humidity.

Adhesion and flexibility

The adhesion of two pack acrylic urethanes to concrete is excellent and the presence of water in the concrete does not cause a problem since it can react with the isocyanate groups present in the adduct. Primers for concrete are often epoxy/polyamide based formulations and adhesion of acrylic isocyanate topcoats to such a primer is also excellent.

Dimensional changes take place in concrete structures as the surface temperatures vary between winter and summer conditions. A degree of flexibility is therefore required in any coating being used to protect the concrete. Treadaway and Rothwell¹ suggest that the system should be capable of passing a 25 mm Mandrel bend. This requirement is well within the capability of acrylic isocyanate systems.

Alkali resistance

The high pH of fresh concrete makes good alkali resistance a pre-requisite for any viable concrete coating. The reasons for the excellent resistance of the acrylic/isocyanate system to alkali has already been discussed earlier in this paper.

Water resistance

When fully cured the highly cross-linked acrylic urethane film produces an excellent barrier to water. This is seen not only in coatings applied on concrete but in many of the other end uses for this class of coating.

Permeability

Effective concrete protection relies on reducing the diffusion of CO₂ and ingress of chloride ions into the concrete. Thompson³ reported that all the coatings that he tested reduced penetration of chloride ions by at least 90%. Robinson⁴ in his CO₂ diffusion studies records that two pack urethane

Continued on p.416

Two-pack epoxy coatings as protection for concrete structures

N. S. Moss, Ciba-Geigy Plastics, Duxford, Cambridge CB2 4QA, UK

The long term objective

"Corrosion" of reinforced concrete structures is a two-fold problem. Firstly that carbon dioxide reacts with the calcium hydroxides in concrete to form a weaker calcium-carbonate structure. Lowering of the pH of the concrete from ca 12 to <9 then results in corrosion of the reinforcing bars by oxygen, water and acidic ions (particularly chloride, which occur on most highways due to deicing and also may be present in the original concrete).

The role of a coating should therefore be to reduce ingress of carbon dioxide (to prevent the lowering of pH), to reduce ingress of chloride and sulphate ions and, by allowing transmission of water vapour but not liquid water, to minimise the transportation of chloride ions already present in the concrete.

The requirements from a coating

A great deal has already been published on the requirements of coatings for the application¹. Summarised, they are as follows:

- Low carbon dioxide permeability.
- Low permeability to ions (chloride, sulphate).
- Good water vapour transmission characteristics (to allow the concrete to lose excess water).
- Low water permeability (to prevent chloride ion transportation and acceleration of reinforcement corrosion).
- Good adhesion.
- Good flexibility and crack bridging properties.
- Alkali resistance (to prevent coating degradation by alkali in the concrete).
- Long service life and recoatability.

Because of the complications in design of most concrete structures the protection requirements with respect to water, humidity temperature etc can vary considerably on different parts of the structure.

In some circumstances it might be appropriate to treat some parts of the structure differently to the main bulk e.g. areas of high humidity, risk of

standing water or high chloride levels or where high hydrostatic pressure may develop from groundwater on the reverse of the concrete structure.

The role of epoxy resins

In the protection of new concrete from reinforcement corrosion, the pre-coating of reinforcement with epoxy powder coatings is becoming widely accepted.

Araldite® epoxy resin systems applied as ambient-temperature-curing two-pack products are also well established as protective coatings for steel and concrete (see Figures 1 to 3) in marine and industrial environments. They are used as a result of their impermeability to a wide range of organic and inorganic chemicals, especially to water and chloride ions, and for their excellent adhesion.

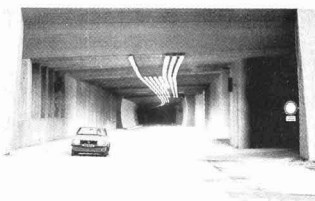
Epoxy resin formulations for coatings can be based on a wide variety of polymeric structures, the types well known are the glycidyl ethers of Bisphenol A, Bisphenol F and phenol novolaks – and it is on this basis that most anti-corrosive epoxy coatings are formulated.

Attention must also be given to the choice of curing agent and levels used. The chemical type of curing agent can significantly influence the performance of the coating, e.g. polyaminoamides form a good basis for epoxy coatings for concrete and will contribute flexibility and effect some improvement in weatherability of the coating. Excess curing agent can however act as an effective transport system for chloride ions whereas systems correctly formulated can favour cation permeation, thereby maintaining pH at a higher level^{2,3}.

Typical performance data for epoxy resin systems of low filler content are as follows.

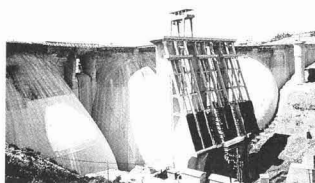
Carbon dioxide permeability — values for epoxy resin based systems are generally in the order of 100-200 $\mu\text{S}\cdot\text{m}$ dependant on the type of epoxy coating, i.e. a factor of 2-4 times the value of 50 $\mu\text{S}\cdot\text{m}$ suggested by Professor Klopfer⁴ as an effective barrier for 100 year protection against penetration to 10mm depth.

Figure 1



Epoxy coatings used to protect the walls of the Arlberg road tunnel in Austria.

Figure 2



Epoxy resin protection for the Agueira Dam in Portugal.

Figure 3



Epoxy coatings used to protect an underground water reservoir.

Anion permeability — the low permeability of correctly selected epoxy systems to chloride and sulphate is adequately demonstrated by the wide use of systems of this type as coatings for protection of steel in chemical storage, marine environments and for the protection of concrete in water storage and effluent treatment.

Previously published work by Haagen and Funke⁵ concludes that, in films of 40-60 μm no chloride ion permeability is evident provided that the films are substantially non-swollen by water. Work by J. D. Murray² using molar concentrations of 0.05 confirms that there is no detectable migration in films where the mix ratio is near to stoichiometric. Higher molar concentrations, which are unlikely over long periods, except possibly at marine locations, show positive migration effects.

Water/Water vapour permeability — low water absorption and permeability are key features of epoxy resin systems and are exemplified by their current usage to protect concrete reservoirs, dams and water processing installations throughout the world.

The vapour diffusion coefficient for cured epoxy coatings varies slightly with curing agent types but can be classed as being ca 1×10^{-8} . This equates to a vapour permeability of ca 10-15 g/m/day. Addition of fillers, especially silicas, can reduce water vapour diffusion further but the diffusion coefficient remains within the same order of magnitude as the unfilled system.

Adhesion — most epoxy systems other than those with very high flexibility have a tensile strength and bond strength to concrete in excess of the tensile strength of the base concrete, e.g.:

Epoxy systems — Tensile strength typically 30-90 MPa.

Concrete — Tensile bond strength typically 4-10 MPa at concrete failure.

Longevity — Long service life is the key factor for protection of concrete. Epoxy resins form a durable protection system under a variety of conditions but systems based on Bisphenol epoxy resins are subject to degradation (i.e. chalking) due to UV radiation. This process can be reduced by the use of high-addition non-aromatic curing agents such as polyaminoamide, careful

Based on Paper presented at the OCCA Thames Valley Section Symposium "Durable and Protective Coatings for Concrete", 4 July 1988, Heathrow, London.

Continued from p.414

systems are among the most efficient of the nineteen systems evaluated for initial and maintained performance over a 3,000 hour exposure period in a QUV Weatherometer. Further, these low diffusion rates were achieved at lower film thicknesses than with many of the other coatings under test. It is quite clear that acrylic urethane systems form the bases of good anti-carbonation coatings. The actual permeability of a given coating depends not only on the binder but also on the pigment and extenders present and the PVC of the final formulation.

Stain and solvent resistance

Acrylic urethanes offer exceptional resistance to most household stains and aggressive organic solvents. In room temperature cured coatings this is only matched by a D/D system. For this reason these finishes are used in anti-graffiti coatings either as a pigmented topcoat or a clear varnish.

Abrasion resistance and toughness

The urethane group enhances abrasion resistance⁵ and they therefore

Based on Paper presented at the OCCA Thames Valley Section Symposium "Durable and Protective Coatings for Concrete", 4 July 1988, Heathrow, London.

filler formulation and addition of UV concrete at dft of 30-75µm per coat.

○ Water dispersible systems can be applied to damp or "green" concrete and can be used as curing membranes on freshly poured concrete.

○ Multicoat paint systems may be used to build up the required 200µm or the water dispersed epoxy may be used as a stabilisers. Nevertheless a gradual chalking and erosion of the epoxy film can be expected. Experience has shown that provided a chalked surface is acceptable, the service life of epoxy applied at 250-500µm can exceed 20 years and that microcracking of the coating is reduced where curing agents of the polyaminoamide type are used.

Types of epoxy system

Solvent-free epoxy systems lend themselves readily to use as:

○ coatings (which could be used overcoated eg with chlorinated rubber for decorative appearance if required)

○ pebble aggregate finishes which combine the corrosion protection with attractive specialist finishes

○ Epoxy mortar renderings, heavily filled for use where a heavy physical barrier to chemical attack is desirable

○ low-viscosity systems for use as sealers, giving partial penetration and forming a thin surface coating.

Water dispersible epoxy coatings

Typically systems such as the 2 part Araldite PY 340/HZ 340 system are used to apply pigmented coatings onto

find application in concrete floor coatings particularly as a topcoat over an epoxy primer where this property combined with good colour allows one to produce pale coatings with a long service life.

Exterior durability

Acrylic urethanes have a proven record for durability in a wide range of end uses and long life and good colour and film integrity is assured⁶.

Recoatibility

At some time in the future repainting will become necessary and the new coating must adhere well to the old. Acrylic urethanes have excellent recoating properties and are greatly superior to a polyester isocyanate "D/D" coating system in this respect.

Conclusions

Two pack acrylic isocyanate coatings are presently used in a number of areas to protect and decorate concrete and masonry surfaces. However the unique combination of high build, good cure even under adverse conditions,

primer coat for other surface finishes.

The desirability of multicoat finishes has been previously stated⁴ in terms of ease of application and reliability of achieving the film thickness requirement uniformly.

○ Water dispersed epoxy may be used in the preparation of polymer modified cement renderings which may be trowel applied.

○ Tar/Bitumen modified epoxy water dispersed coatings provide further improved barrier properties.

Conclusion

Epoxy systems have a role for use as primer coats for concrete in multicoat systems where high adhesion is required and as total coating systems for concrete structures where there are largely functional performance requirements — i.e. when protection against unusually aggressive environments is of primary importance.

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excellent weathering properties and high resistance to a variety of chemicals, stains and water, warrants a closer look at this class of coating by the paint companies looking for longer lasting aesthetic finishes for concrete protection.

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A survey of Romano – British wallplaster

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The survey nearing completion at the University of Leicester, is aimed at producing a database of information on the materials and technology of Romano-British wallplaster, mortar and painting. This will be compared with the advice of the classical writers Vitruvius and Pliny.

The classical authors Vitruvius¹, writing around the first century B.C., and Pliny² A.D. 23 to A.D. 79, gave much advice on the construction of buildings.

The materials described by these writers are those generally available to them in and around Italy, such substances as active volcanic earths and lava not being found in Britain. These substances are worth commenting on as they considerably improved the properties of mortar. The material invariably used for mortar and plaster making was lime, mixed with various fillers or aggregates. Both hydraulic and non-hydraulic limes appear to have been recognised and used. The addition of dry volcanic earth or pumice, natural aluminosilicates, gave mortars much greater strength and water resistance, and could on occasion even set under water. Where volcanic deposits were not available, crushed brick, tile or other ceramics were used, giving similar results. Mortar containing volcanic or ceramic aggregates was called "opus signinum" and this is commonly found in Britain with the use of brick or tile as the filler. It was used as a water resisting layer in floors, walls and as a lining of water tanks or pools and was sometimes cast as a concrete like material. The mortar in the Roman bath at Bath, for example, is largely of opus signinum type, particularly where water or moisture comes into contact with the construction. Even after some 1700 years it is often still in very good condition.

As mentioned above, Roman mortars and plasters are usually lime based, although the use of gypsum for plaster work is reported by Pliny. The source of lime being chalk, various limestones and for very white plaster, white marble, some types of limestone with a sufficiently high clay content would give hydraulic lime. In Britain a similar range chalk and limestone was used, the limes used varying from area to area.

Generally it seems that the nearest suitable material to hand was used. Where these do not correspond to local materials trade and transport is obviously indicated.

A wide range of building techniques have been found in Britain, from wattle and daub or mud brick to tile bonded dressed stone. Even where walls do not survive, materials were frequently re-used in Roman and later times, the plaster was of little use and considerable quantities are found. Although even this was sometimes crushed up and re-used as an aggregate for new plaster work. The plaster often has on its reverse side signs or impressions of the type of wall or ceiling it came from. Mud itself does not usually remain unless the building was destroyed by fire, but the impression of keying or wooden wattle is preserved in the plaster.

The classical writers suggested that walls should be plastered with three base coats and three top coats, each applied before the previous layer had dried. The survey has shown that often only three layers altogether were used, up to two layers as base and one or possibly two very thin finishing coats. The recommendations for the use of crushed marble in the finishing layers have been found in only three sites to date, and the material is crushed coarse grained calcite crystals rather than marble. This was probably imported.

The final decoration, if any, was applied to the final layer of plaster. For brightness of colour, this top layer or *intonaco* was fine white lime, further improved by the use of refractive aggregates such as marble dust as mentioned previously. The technique favoured by the Romans was that of true or *buon fresco*. The pigment, simply as a slurry in water, was applied directly to the *intonaco* whilst it was still wet. As the lime sets by carbonation, the water evolved containing some slaked lime in solution rises to the surface incorporating the pigment which becomes bonded onto the *intonaco*. The quality of the bond depends very much on the state of the *intonaco* at the time of painting. The process requires considerable planning as, if detail is required in the painting such as figures or landscapes, only fairly

small areas can be painted in one session. This leads to the wall being divided up into sections, small enough to be painted before the plaster dries or sets. These are known as *giornate di lavoro*, literally a day's work. The junction between sections can often be seen although they were deliberately made to coincide with features of the painting such as: panels, columns, borders, etc. For painting large areas of colour the *intonaco* itself may have been coloured by the addition of pigments or the use of brick or tile dust for pink to red colours. Where the plaster had already dried or where over painting was necessary, the technique of *fresco secco* could be used. Here the pigment was mixed with lime water instead of water. The bond tends not to be as good as for *buon fresco*. An alternative method was to use some form of organic medium or *tempora*. Many substances were recommended such as: egg, both yolk and white, animal glues, natural resins and drying oils. Another variation was the use of wax as a medium, the so called encaustic method, applied with hot implements. None of these organic media have been seen in the survey, but they may well not have survived burial. There are examples of overpainting which are probably *fresco secco*.

The pigments used are mainly natural: white – pure lime, black – soot or charcoal, red to brown – red ochre – haematite and goethite or burnt limonite, yellow – yellow ochre – limonite, green – green earth – glauconite, Figure 1, and are all quite common. Blue is invariably the manufactured material Egyptian blue, a copper calcium silicate. It is chemically the same as the blue of Egyptian faience, Figures 2, 3. Being glass like, its particle size affects its apparent colour. When coarse, light is refracted giving an intense blue. When fine, more light is reflected giving a lighter colour.

It was probably imported, as was cinnabar, mercury sulphide, the natural version of the pigment vermilion, its brilliant red colour being very distinctive. The orange red pigment, red lead, has been found in only one sample to date, whilst cinnabar has been found on some 17 sites around the country. Pliny cites cinnabar as one of the expensive pigments, at 70 sesterces per Roman pound, calculated at today's prices at about £350 per 320 g, and as such it was to be supplied by the patron to the painter. Interestingly cinnabar becomes rarer towards the end of the Roman occupation of Britain, often being diluted with red ochre, perhaps due to reasons of economic instability and transport difficulties. Another imported pigment was the brilliant

Figure 1

Fossiliferous glauconite nodule from Dover.

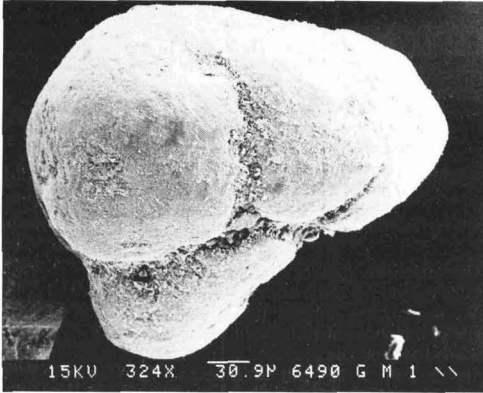


Figure 2

Egyptian blue from Colchester.

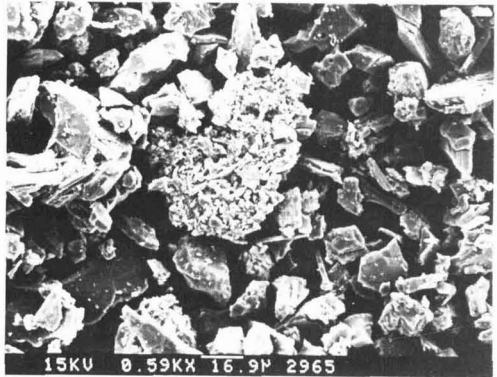


Figure 3

Egyptian blue from Colchester.

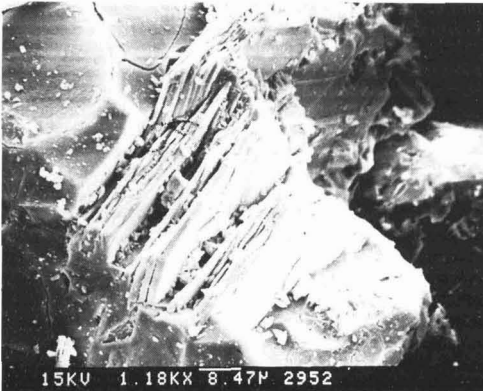
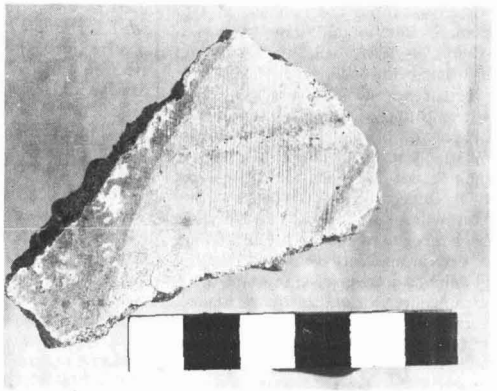


Figure 4

Brush marks from Wall, Staffordshire. (1 cm scale)



yellow orange of realgar, arsenic sulphide, which has been found only in conjunction with other pigment samples and not actually on wall paintings to date. A possible paint material is madder lake, once again found in contexts of other pigments only.

Whilst not actually a pigment, gold leaf has been found on one sample, presumably originally stuck on with some form of adhesive. Pliny mentions many other pigment materials including: indigo, azurite, lapis lazuli, malachite, and organic dye materials used to colour chalk or other bases. None of these have been confirmed in this project.

The samples of painted plaster examined during the survey have very often been in very good states of preservation, being: bright and well bonded. Even on burnt samples, perhaps heated to 400°C, colours remain more or less intact, although

iron pigments do tend to redden if heated to higher temperatures or for prolonged periods³.

The thickness of the layers of plaster and paint are quite varied. The plaster can be from 1 to 10 cm or more, in one or more layers. The lime content was often between 15 to 25%. Chopped grass or straw was often added to plaster, much in the same way that hair was added to medieval plaster. Where dampness was a problem, or where it could occur, opus signinum type plasters were used, with a lime content of about 25 to 30%. The intonaco layer was often very thin, from 0.5 to 1 mm thick, although up to 4 mm thick is known, with a lime content of about 95%. Thin layers may have been brushed on, but the float seems to have been the usual method of application. The paint layers are usually in the order of 0.01 to 0.05 mm thick. Thicker layers of paint, around 0.1 mm thick do occur

on occasion, but tend to be very friable. The paint was apparently usually brushed on as brush marks often survive. Figure 4. Intonaco and paint layers were sometimes burnished or polished, giving hard flat surfaces. Figure 5 may show this. The writer would welcome other ideas on possible interpretation. Where very grainy paint was used, such as coarse green earth or Egyptian blue, the intonaco was sometimes combed to provide ridges for retention of the pigment.

When a room was to be re-decorated, two options were available to the Romans. Either strip off the old plaster and re-plaster and re-paint, or roughen up the old plaster by pecking with a plasterer's hammer, re-plastering and repainting. The second course meant that the room became smaller. Examples are known of five replasterings, each being about 1 cm thick!

Continued on p.428

Maintenance painting of exterior timber

by J. Boxall and G. A. Smith, Department of Environment, Building Research Establishment, Princes Risborough Laboratory, Princes Risborough, Aylesbury, Buckinghamshire HP17 9PX, UK

Summary

This paper presents results from an exposure trial performed at PRL to study the performance of maintenance paints on exterior timber.

A range of commercial water and solvent-based paints were applied to previously painted softwood cladding which had been prepared by one of three techniques; sand-blasting, burning-off and mechanical sanding. Paint performance after 30 months exposure was generally inferior on these cleaned surfaces compared with that found on new wood, though certain examples of water-borne paint performed well, and the performance of this group as a whole was superior to the solvent-borne paints.

The results show that tolerance for imperfect surfaces should be regarded as an important formulation requirement of paints for exterior timber.

1 Introduction

Over the last few years many new paints specifically designed for use on exterior softwood timbers have been introduced on to the UK market¹. The higher levels of performance from these new products are achieved by manufacturers optimising the most important properties required for use on exterior timber, namely, good inherent durability, a retained high level of extensibility, and good wet adhesion. Manufacturers marketing these new products have taken different formulation routes in order to achieve these requirements. Two main groups can be readily identified; those who have chosen to use water-borne emulsion technology, and those who have used the more traditional approach of using solvent-borne technology.

Previous studies at PRL² have shown that many of the paints based on novel technologies do offer performance advantages over the still widely used general-purpose alkyd paint systems.

The work was performed however, on new, unweathered, softwood, and left unresolved the question of paint performance in the maintenance situation where substrate condition is often poor and difficult to rectify. The work reported here addresses this issue, and involved the exposure testing of water- and solvent-borne paints over a 30 month period.

The paints were applied to previously painted softwood cladding which had been prepared by one of three techniques; sand-blasting, burning-off and mechanical sanding. Performance over these substrates was assessed in comparison with new wood.

2 Experimental

2.1 Paints tested

A total of ten proprietary paints were tested, comprising five examples each of water-borne and solvent-borne systems, Table 1. All of the paints were white. Whilst all of these paints were readily available in the UK, four were imported products.

2.2 Panel preparation

Two sources of timber were used:

(i) Painted tongued and grooved Baltic redwood cladding reclaimed from local authority housing. These boards were approximately 10 years old and had been repainted at least once with traditional alkyd paint, which was in poor condition.

(ii) New Baltic redwood, obtained as planks.

The reclaimed boards were cut to 1000 mm lengths ensuring that all damaged end-grain was removed. Existing tongues and grooves were removed and new ones machined to give an overall dimension of 1000 × 83 × 15 mm (excluding tongue). The paintwork on the faces was otherwise untouched.

The new timber was prepared to the

same design and dimension and had a planed finish. After machining, a proprietary grade of water-repellent preservative was applied by a double vacuum process, conforming to the redwood cycle, category B in Table 2 of BS 5589³. All boards were then equilibrated indoors for one month.

The boards were nailed together in assemblies, as shown in Figure 1, using galvanised nails on the top and middle battens and mild steel wire nails on the bottom batten. Prior to assembly the backs, tongues and grooves of each board, and the battens, received one coat of the first coat of the paint system to be tested on the faces. The reclaimed boards were fixed in the assemblies with the existing paintwork exposed outwards.

Altogether 40 panels were prepared, 10 from new wood and 30 from the reclaimed cladding. These were grouped into 10 sets of 4 panels (1 new, 3 reclaimed), one set for each of the test paints.

2.3 Surface preparation

The assemblies made up from new wood were left with a planed finish. The typical surface appearance of these boards prior to painting is shown in Figure 2.

The assemblies made up from the reclaimed boards were prepared for overpainting by sand-blasting, burning-off or sanding.

2.3.1 Sand-blasting

The assemblies were taken to a local authority housing estate where painted cladding was being sand-blasted as part of a maintenance programme. The assemblies were sand-blasted by the contractor on site. The time taken to clean each assembly was approximately 35 seconds, and the typical surface condition after cleaning is shown in Figure 3.

2.3.2 Burning-off

A propane-fuelled blow-torch was used to burn-off as much paint as practicable, subsequently followed by hand sanding to remove surface char. The time taken to clean each assembly was approximately 30 minutes, and typical surface condition after cleaning is shown in Figure 4. An attempt was made initially to use a hot air-stripper to clean these boards, though this had to be abandoned when it became apparent

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Figure 1
Side and plan view of board assemblies

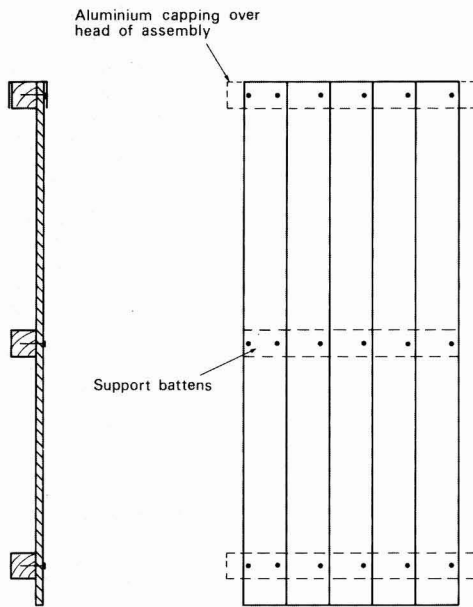


Table 1
Paints used

Code No	No of Coats	Product description	Finish appearance
Water-borne paints			
1	3	Alkyd-acrylic paint	Low sheen
2	3	Vinyl-copolymer paint	Low sheen
3	1	Acrylic primer-undercoat	
	2	Acrylic topcoat	High sheen
4	2	Acrylic primer-undercoat	
	1	Acrylic topcoat	High sheen
5	1	Acrylic primer-undercoat	
	2	Acrylic topcoat	High sheen
Solvent-borne paints			
6	1	Semi-transparent primer (alkyd)	
	2	Alkyd topcoat	Low sheen
7	1	Alkyd primer-undercoat	
	2	Alkyd topcoat	Low sheen
8	1	Alkyd primer-undercoat (as 7)	
	2	Alkyd topcoat	High sheen
9	1	Oleo-resinous wood primer	
	1	Alkyd undercoat	
	1	Alkyd topcoat	High sheen
10	1	Alkyd wood primer to BS 5358	
	1	Alkyd undercoat to Def Stan 80-59/1	
	1	Alkyd topcoat to Def Stan 80-59/1	High sheen

that it was not softening and removing the paintwork.

2.3.3 Sanding

Sanding was performed by orbital sander to remove as much paint as practically possible. The time taken to clean each assembly was approximately 8 minutes. Typical surface condition after cleaning is shown in Figure 5.

2.4 Paint application

After surface preparation all of the assemblies, including those prepared with new wood, were filled as necessary using a proprietary emulsion-based exterior wood stopper. Knots were treated with a proprietary shellac knotting to BS 1336; the set of four assemblies that were to be overcoated with paint system number 1 were knotted with the manufacturers specified sealer.

The paints were all brush applied in the three-coat systems as shown in Table 1, with manufacturers recommendations concerning thinning being followed as required. Paints were applied to the faces, edges and end-grain of each assembly, allowing approximately one week between coats. The backs of the panels were protected by the previously applied coat of primers. It was noted during application that the relatively rough textured sand-blasted assemblies took approximately twice as long to paint as the other surfaces, and consumed twice as much paint.

2.5 Exposure testing

Two weeks after painting, the assemblies were exposed on south facing 45° racks at the Princes Risborough Laboratory, an inland, semi-rural site approximately 100 metres above sea level. Prior to exposure the top edge of each assembly was covered with aluminium flashing to prevent water entry, Figure 1. Exposure commenced in July 1984.

2.6 Assessment

Paint condition was assessed visually every three months over a period of 30 months using a six-point rating scheme. This scheme was based on the principles described in British Standard BS 3900:Part H1:1983, 'Methods of test for paints: Designation of intensity, quantity and size of common types of defect: general principles and rating schemes'. The standard is identical to ISO 4628/1-1982.

Gloss level measurements were also made at three monthly intervals using a

Figure 2
Appearance of assemblies made from new wood

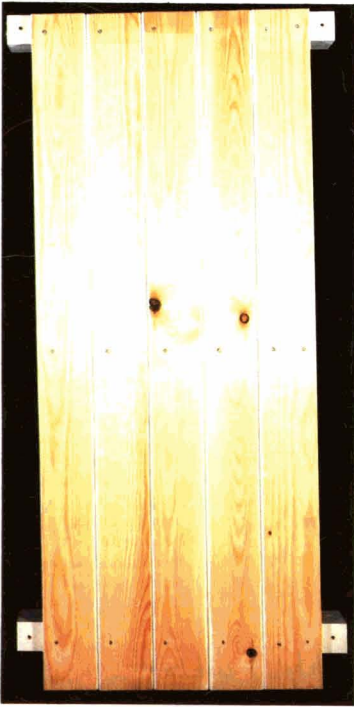


Figure 3
Appearance of assemblies cleaned by sand-blasting



Figure 4
Appearance of assemblies cleaned by burning off

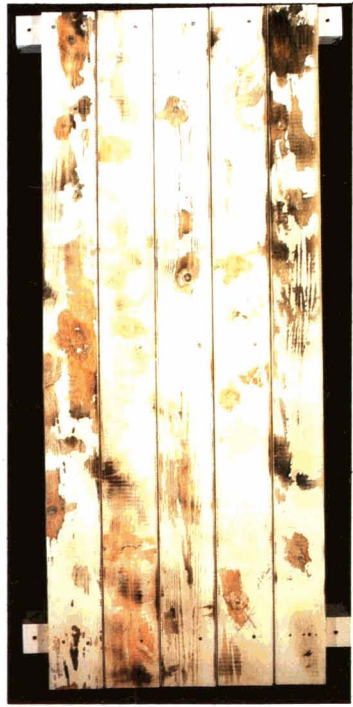


Figure 5
Appearance of assemblies cleaned by mechanical sanding

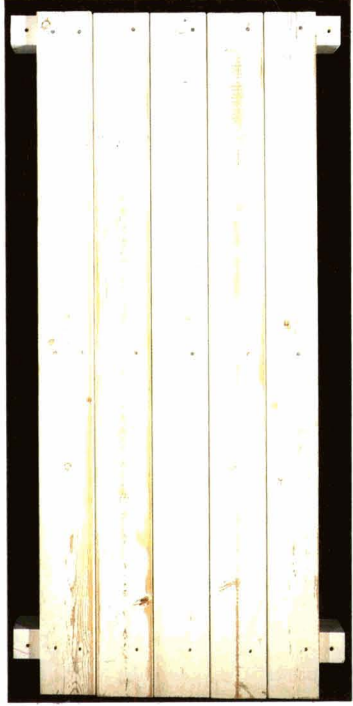
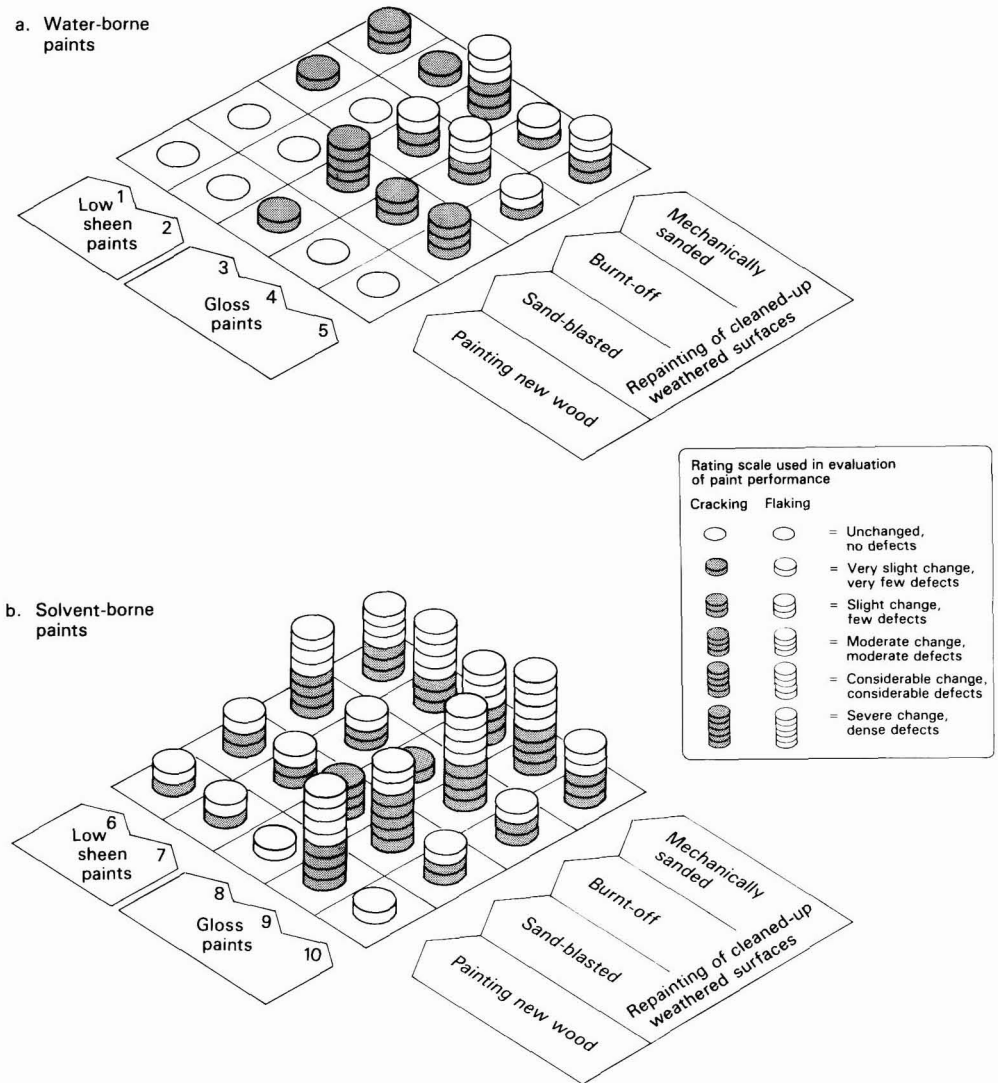


Figure 6

Performance ratings after 30 months' natural exposure for paints applied to new wood and to cleaned-up weathered surfaces



60° glossmeter. Measurements were taken at a central position on each of the five boards comprising an assembly and the mean value determined for each paint-substrate combination. The surfaces were not washed prior to measurement.

Results

3.1 Paint condition

The large volume of data obtained from the three monthly panel

inspections has necessarily been summarised for this paper. A summary of the incidence and severity of two 'key' indicators of durability, film cracking and film flaking, after 30 months of exposure, is given in Figure 6.

3.1.1 Performance of water-borne paints (numbers 1-5)

The performance of this group of paints was generally of a high order. The low-sheen finishes, 1 and 2, were in

particularly good condition at the end of exposure, and these two paints showed the highest level of performance of all of those evaluated in this study. The only integrity failures here were minor cracking over the substrates prepared by burning-off (Paint 1 only) and mechanical sanding. Paint 2 was also adversely affected by a patchy discolouration. The three acrylic gloss paints, 3 to 5, performed less well. Cracking was more widespread with failure being evident over sand-blasted surfaces for all of the paints and on new

wood with paint 3. Minor flaking was evident with all of the acrylic gloss systems cleaned by burning-off and mechanical sanding.

3.1.2 Performance of solvent-borne paints (numbers 6-10)

The overall performance of this group of paints was inferior to that of the water-borne group. Film cracking and flaking had occurred on nearly all combinations of paint and substrate after the 30 month exposure period, and integrity failures also developed more rapidly during weathering, Figure 7.

A spread of performance was again shown with best results being found with the alkyd gloss paints 8 and 10. The worst performance of all was shown by one of the conventional paint systems, 9, with the first signs of integrity failure here being observed, on all of the substrates, within three months of exposure. The low-sheen finishes, paints 6 and 7, showed a similar level of performance to the gloss paints 8 and 10 in respect of film integrity, though paint 7 was especially prone to severe mould disfigurement and also developed a pronounced yellow discolouration.

One further noteworthy difference apparent throughout the exposure was the extent of nail-head corrosion. On the mild-steel fixings, this developed more rapidly, and was always more pronounced with the solvent-borne paints than for the water-borne products. None of the paints showed appreciable corrosion staining over the galvanised fixings.

3.1.3 Gloss level

Changes in gloss level during the 30 months exposure period for water-borne and solvent-borne paints are shown in Figures 8 and 9 respectively. The data presented here have been selected to show principal trends, and accordingly refer only to the high-sheen paints applied over the assemblies prepared from new wood. The results show a basic similarity in behaviour within the groups though there are clear between-group differences. The water-borne paints started with a slightly lower sheen level and exhibited a more rapid loss of gloss than the solvent-borne paints, though at the end of the exposure period the gloss levels for the two groups were broadly similar.

3.2 Substrate effects

The performance of the paints tested varied depending on the surface condition of the assemblies, Figure 6 and Table 2.

The low-sheen water-borne paints

Figure 7
Film cracking during exposure

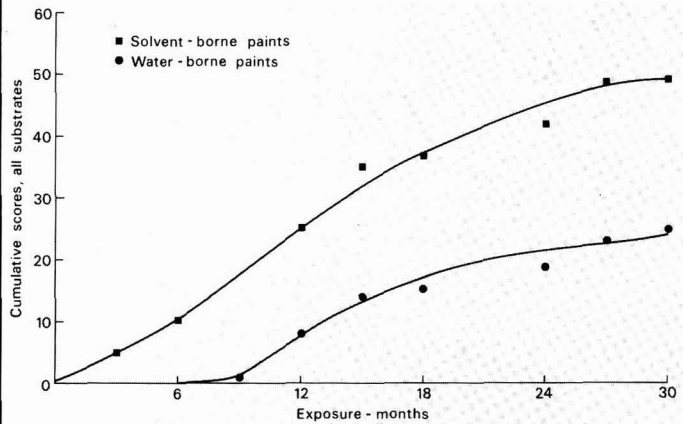


Figure 8
Changes in gloss level of waterborne paints

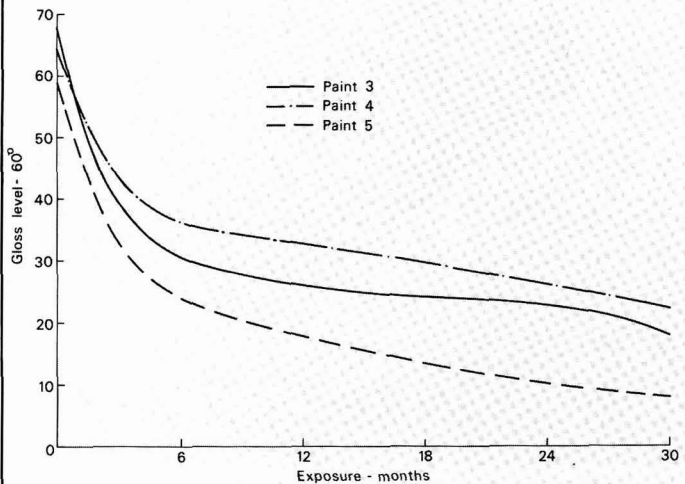


Table 2
Effect of substrate: Median performance ratings of paints after 30 months.

Paints	Substrate	Median performance ratings for:	
		Cracking	Flaking
All paints	New wood only	0	0/1
	Cleaned previously-weathered:		
Water-borne	All surfaces	2	0
Solvent-borne	All surfaces	3	2
	Cleaned previously-weathered:		
All paints	Sand-blasted	2	0
All paints	Burnt-off	2	1
All paints	Mechanically sanded	3	2

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showed the highest tolerance to the cleaned previously-painted surfaces, and here performance was nearly as good as over new wood. None of the other paints tested however, performed as well as on new wood.

Film cracking occurred over all of the cleaned assemblies and was the main integrity failure found over sand-blasted surfaces. Cracking was most severe over surfaces which had been mechanically sanded. Film flaking was least pronounced on the sand-blasted assemblies, where its occurrence was similar to that on new wood. In comparison flaking was most severe over the mechanically-sanded surfaces with an intermediate level of flaking on the surfaces which had been burnt-off.

The locus of these integrity failures varied depending on the substrate. On the assemblies prepared from new wood, failure was initiated from board edges and nail holes, whilst on the sand-blasted assemblies failure was by the development of fine cracking along the ridges created by the abrasive. Over the burnt-off and mechanically-sanded surfaces failure was more localised and was apparently initiated and/or aggravated by embrittlement of areas of the underlying alkyd paints which were not removed by the cleaning operations.

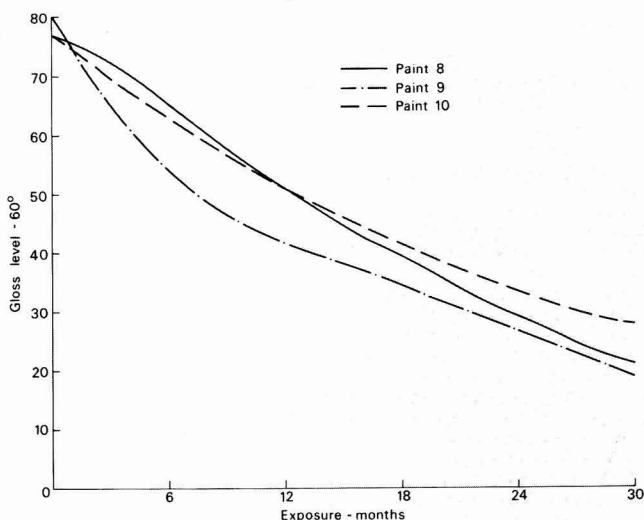
4 Discussion

The results from this study were analysed using standard Kruskal-Wallis and Mann-Whitney non-parametric statistical testing procedures⁴, with significance levels set at $P < 0.05$, Appendix 1. The results demonstrate clearly that old painted wood presents a much more difficult painting substrate than new wood, and that the most common methods of removing paint, sanding and burning-off, can fail to raise the level of paint adhesion to that obtained on new wood. The work also shows that paints differ in their tolerance to previously painted surfaces.

4.1 Paint performance

The highest level of performance of all of the paints tested was shown by the low-sheen water-borne paints 1 and 2, based on alkyd-acrylic and vinyl copolymer respectively. In comparison, the high-sheen (acrylic gloss) water-borne finishes (3, 4 and 5), based on broadly similar acrylic resin technology, performed significantly less well, especially on the maintained surfaces cleaned by burning-off and mechanical sanding, where some flaking was evident after 30 months. Nevertheless, the overall performance of the water-

Figure 9
Changes in gloss level of solvent borne paints



borne group was good, and on almost every assessment criterion used they have outperformed the solvent-borne group of finishes.

A wide spread of performance was shown by the solvent-borne paints, with the high-gloss finish (paint 8) having the best durability within this group. This product consisted of a primer and two coats of gloss finish and, as might be expected, performed better than the two paints 9 and 10 containing conventional undercoat. Lack of extensibility in undercoats and the reduced level of system performance consequent upon this has been appreciated for some years now^{5,6} as has the need for all parts of the system to be formulated to meet the requirements for durability on exterior timber. The performance benefits from tailoring the system for a timber substrate can be seen by comparing the performance of the two traditional alkyd gloss paint systems 9 and 10. Paint 10 based on the British Standard primer and with top coats conforming to Defence Standards, both of which specify minimum durability requirements, was clearly far superior to the non-specification paint 9, the performance of which, even on new wood, was so bad as to render it unfit for purpose.

The two low-sheen alkyd finishes 6 and 7 did not perform as well as the best of the high-sheen paints 8 and 10, though they possessed performance advantages compared with the poorly formulated gloss paint 9. It is possible that the high pigmentation levels in

these low-sheen solvent-borne finishes makes retention of flexibility far more difficult than in similar formulations based on water-borne technology.

The results found here are clear endorsement of water-borne paint technology, in respect of outdoor durability on new wood and in maintenance repainting. However despite the lower level of performance even from well-formulated solvent-borne paints, it must be recognised that they possess several advantages compared with water-borne paints and there are situations where their use would be more appropriate. In particular, water-borne paints are less tolerant of adverse weather conditions on storage, and during and immediately after application, and this limits their use in the winter months. Furthermore, they cannot be used over fresh putty without serious loss of appearance and there are greater risks of self-adhesion (blocking) between contacting surfaces; these latter two characteristics are particularly important when painting window joinery.

Water-borne paints at their present stage of development also do not commend themselves where a high initial gloss level, together with good gloss retention, is a prime requirement.

4.2 Surface preparation

The results from this study confirm the problems of obtaining good paint performance in the maintenance situation. Of the three cleaning techniques evaluated, sand-blasting,

burning-off, mechanical-sanding, none raised the general level of paint performance to that obtained on new wood, though sand-blasting was effective in reducing the severity of flaking.

On surfaces cleaned by mechanical sanding in particular, failure of the test paints was apparently initiated and/or aggravated by cracking in the underlying, old coats of paint, which the restoration technique did not remove because they were adhering too well. Many of the paints were not severely affected, but the general-purpose alkyd gloss paint system 9 which was subject to rapid hardening exacerbated the problem and was the subject of almost total failure. In practice, cost constraints will often prevent complete paint removal to a fresh wood surface, and good tolerance to imperfect paint coatings should be regarded as an important formulation requirement for exterior paints for timber.

The sand-blasting techniques currently used to clean exterior timber are not easily controllable with, for example, limited scope for precise control of surface profile. In this work, it appears that the profile created by the sand-blasting of the panel assemblies has not provided a fully suitable painting surface, with cracking along the ridges of the profile being a particular problem. Modification of the operating conditions to achieve a finer texture to the wood would almost certainly have been beneficial.

Despite the relatively poor showing with respect to paint cracking found here, some benefits in respect of reduced flaking were realised which, it is considered, does demonstrate the potential of sand-blasting. Future work is planned to study the influence of surface roughness on the paint-holding capability of exterior softwood.

5 Conclusions

The results from a 30 month period of accelerated natural weathering have confirmed the general problem of obtaining adequate paint durability on exterior softwood, especially in the maintenance situation. Substrate condition was found to be of major importance, with a generally lower level of performance being found on the surfaces cleaned by sand-blasting, burning-off and mechanical sanding, compared with new wood. Paints have however, been identified that perform well on cleaned previously-weathered surfaces, and it is now clear that paints intended for maintenance use on exterior timber should be evaluated by manufacturers for their ability to perform well on imperfect surfaces.

Water-borne paints have demonstrated good performance in previous PRL work on new wood^{2,7}, and are shown here to perform well in the maintenance situation. Concern that water-borne paints might lack adequate tolerance for use over old alkyd paint surfaces would seem to be unfounded. Performance of solvent-borne (alkyd) paints has been found to be rather more mixed, and though some products performed reasonably well, none equalled the performance of the best water-borne systems. It is noteworthy that the paint systems that performed well in this study are known to be representative of types that exhibit good long-term retention of extensibility^{6,8}. This further endorses the prime importance of this property in paints for exterior timber.

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Appendix 1

Significance testing

Significance testing of the performance of water-based paints (1 to 5) against solvent-based paints (6 to 10).

Factor	Median differences in performance ratings and level of significance of differences	
	Water-based	Solvent-based
Performance over all surfaces:		
Cracking	1	2
	**	
Flaking	0	1

Performance over cleaned-up surfaces only:		
Cracking	2	3
	**	
Flaking	0	2
	**	

Significance testing of paint performance over new and cleaned-up surfaces

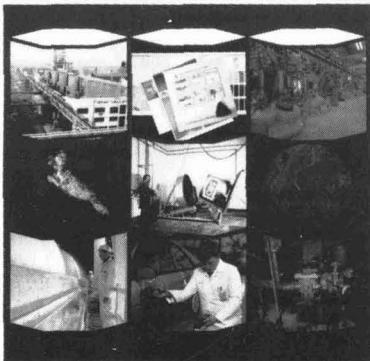
Factor	Level of significance of performance differences			
	New wood	Sand-blasted	Burnt-off	Mechanically-sanded
All paints, bulked cracking and flaking ratings (ie the two scores for each paint added together)	1	3	3	5
	*			
	**			
	*			
	*			

Note: * = significant at 5% level, ** = significant at 1% level and *** = significant at 0.1% level.

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Continued from p.418

Figure 5
Burnished brushed surface from Colchester. (1 mm scale)

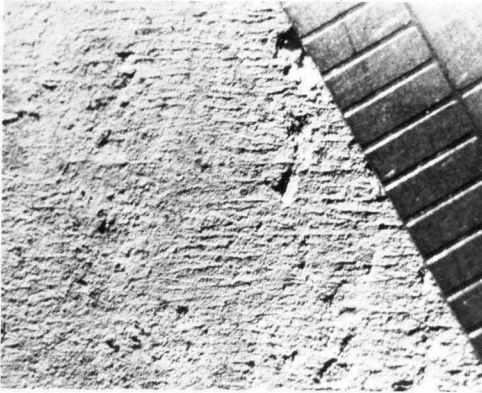
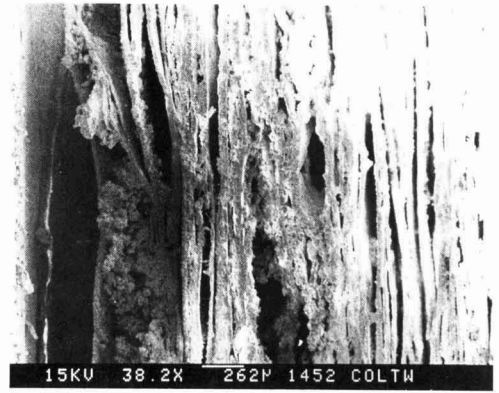


Figure 6
Whitewash from Colchester town wall.



Recent excavation at Colchester suggests that some town walls were whitewashed. A section of the white-wash is shown in Figure 6. There were about 50 layers of pure lime (95% soluble), averaging 0.1 mm in thickness, ranging from 0.05 to over 1 mm. The excavator considers this to represent re-whitewashing every two years⁴.

The work is continuing and will be published in due course.

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UK based members will notice that VAT is no longer applied to their membership subscriptions and for those members who pay their own subscriptions and are unable to reclaim VAT, the total payment required for 1989 at £37 will be less than the £39.10, including VAT, paid in 1988. Council, quite correctly, have taken the decision not to seek to benefit from a large increase in subscriptions for 1989, based upon the reduction in total amount required now that VAT is no longer applicable.

The removal of VAT from subscriptions has been agreed after protracted discussions with the Customs & Excise and brings the Association into line with a majority of UK based societies and professional bodies. Negotiations are now under way to recover the VAT on subscriptions already paid. Although at this stage it is unlikely that the Customs & Excise will allow this claim, based on the administrative difficulties in the identification of and refund to individual members, it has been

suggested that any VAT reclaimed could be used to establish a benevolent fund to aid members in distress. Such a proposal is worthy of consideration in its own right, irrespective of the source of funding. Given the ten months taken to argue the case not to subject membership subscriptions to VAT an early resolution of the refund of VAT is not expected. In the meantime, I would like to hear your comments on the establishment and application of a benevolent fund.

Members will also notice that there is the opportunity, when completing their subscription form, to include an optional subscription to the Journal of Coatings Technology published by the FSCT. The reduced subscription rate of £33 for 12 issues of the JCT to be published in 1989 represents good value for money.

Ladies' Evenings

With the coming of autumn, the annual round of OCCA Sections' Ladies' Evenings is again upon us. At the time of writing this column the Manchester and Midlands Sections have already held their events and with the Irish, West Riding and London Section evenings to be held before the year end. The Thames Valley, Scottish, Newcastle and Bristol Dinner Dances took place early in 1989. All OCCA Ladies' Evenings are well organised, good value for money and great fun. The success of the events says a lot for the Association, its members and the industry. If you have not attended an OCCA Ladies' Night, make sure you do – you will not be disappointed. Those of you who regularly attend should seriously consider fitting a second evening into your diary and perhaps support Thames Valley or Bristol evenings on 31 March and 21 April 1989 respectively. These small and diffuse Sections are worthy of your support.

Pigments & Resin Show

The Association was pleased to

attend the 11th Pigments & Resins Show at the Amsterdam Marriott Hotel, to meet OCCA Members, to promote the Journal and obtain technical articles and to sell advertising space.

Whether you prefer the hotel style exhibition or the more open plan SURFEX approach, these get-togethers represent a most cost effective and convenient way to meet friends, clients, customers and take a snapshot of the industry. It is a moot point whether they provide an opportunity to see new products and the general consensus was that there was not much new on display at Amsterdam. Nevertheless, the organisers have arrived at a formula that works, or at least has been successful for a number of years, and are to be congratulated.

During the visit to Amsterdam, discussions were held with the Secretariat of FATIPEC, the European Federation of surface coating technical bodies. OCCA is not a member of the organisation, although its members attend and lecture at the biennial FATIPEC Congresses. The member countries of FATIPEC transcend the European community boundaries and national organisation host the Congress in turn. Although the Association has considered membership of the Federation on a number of occasions, it has never made a formal application to join. Membership could well fit in with the policy of the Association to build strong links with other relevant organisations and it is likely that formal consideration of membership will take place at the February meeting of Council. What is certain is that the Association will have a presence in Europe in 1992.

Forthcoming OCCA Events

14-15 March 1989
Jnt OCCA/PRA Symposium "The Role of Surface Coatings in Fire Protection", Heathrow, London.

21-24 June 1989
OCCA Chester Conference.

Manchester Section

Newspaper inks

The first printing ink lecture of the 1988/89 session entitled "Newspaper Inks - The 1990's Technology" was presented by Messrs G. Burdall and S. Lilley of Usher Walker plc. The meeting was held at the Silver Birch, Birchwood Centre, Warrington, and was attended by 110 members and guests.

The development of newspaper inks is inter-dependent with developments in the printing of newspapers. The history of the development of newspaper printing was outlined and current new innovations such as the introduction of high speed presses and colour described.

Printing inks dry by three basic processes:

- (a) Penetration
- (b) Evaporation
- (c) Polymerisation

The old process of rotary letterpress printing was outlined and the reasons why a non-drying ink has to be used was explained. This type of press and the types of ink associated with it are being replaced and one can see no future for development within this field.

An advance of rotary letterpress is anilox letterpress in which the roller chain has been replaced by an anilox roller. This gives very even ink distribution, and drying inks can be used such as water based emulsions or evaporation drying inks. Other types of inks being looked at in this context are those which require an external agency such as IR to induce drying.

Current modernisation of the newspaper industry involves the replacement of the old rotary presses with offset lithography presses. Future trends in this field are towards faster press speed resulting in an appreciable increase in the temperature of the rollers, no-rub inks, and increased user tolerance in the inks, with the possibility of the introduction of

outside drying agencies. It will be a requirement for founts and inks to be developed together in order to obtain the best possible results.

Flexography is being introduced into newspaper printing to a limited extent. One national newspaper is already on limited production by this method, with full production expected in early 1989. Drying inks can be used with these presses, and water based inks have been developed in this field, and these have much better rub-resistance.

In summarising it can be said that the old rotary letterpress is redundant, however there is a future for anilox letterpress in conjunction with drying inks. Before long most UK newspapers will be printed by offset lithography, and flexographic printing has now passed through the development stage, however ink development in this field will depend on how this process is adopted.

The lecture was followed by a prolonged question and answer session, the vote of thanks was proposed by Mike Serene, and those present were then able to participate of a buffet courtesy of Usher-Walker.

M. Langdon ■

Newcastle Section

Protective coatings

Some 38 members and guests assembled at St Mary's College, University of Durham, on 6 October 1988 for the first lecture of the 1988-89 session. This was given by Herr D. H. Klein of Dow Chemicals Europe and was entitled "Environmentally Friendly Protective Coatings."

Herr Klein defined the subject as being the protection of metal and concrete against the ravages of aggressive environments, using ambient-curing thick coatings which, themselves, do not damage the environment. Of the factors involved in ensuring good coating performance, he suggested that the binder is most important, and he

proposed to concentrate mainly on epoxies during the evening: such resins have curing mechanisms which do not liberate fugitive products to the environment and, though often showing early chalking on exposure, lose film thickness at only 3 to 8 μm per annum, ensuring long life from thick (100 μm plus) films.

He illustrated typical molecular structures, linear and cyclic, with curing mechanisms, for various solvent-free/high solids and aqueous epoxy systems, such as Bisphenol A, Bisphenol F and novolac epoxies, cured with alternative polyamines e.g. aromatic (MDA), cycloaliphatic (IPD), Mannich Base and reactive polyamide. Differences in reactivity between three Dow polyamide resins, DEH 11E, 12E and 14E, were shown and the effects of cross-link density on pot life, cure-rate, physical properties and chemical resistance were apparent.

Recommendations for a high-solids anticorrosive coating were made, based on aromatic amine-cured oligomeric epoxy resin containing a small proportion of reactive diluent. Pigmentation alternatives covered the range of commonly agreed inhibition mechanisms - anodic passivation, cathodic protection, anodic phosphating and ion-exchange. One drawback, arising from the resin system, is the necessity for labels to bear the skull and crossbones marking: nevertheless such resin/curing agent systems are used successfully for coating pipelines and wine storage vessels and Herr Klein felt that, so far, no viable technical/economic replacement has been found for MDA; further all amines are dermatitic to varying degrees and the fully cured MDA-epoxy coating is totally non-toxic and non-sensitising.

High-solids and "Solventless" formulations, based on new or experimental resins, DER660x80, XZ86733 and XZ95328 were shown. The advantages of solventless coatings with respect to film build, environmental safety and increased performance over

solvent-containing types were stressed: the disadvantages of shorter pot life and higher viscosities could be overcome by hot dual-feed application or the use of polyoxymethylene diglycidyl ether reactive diluent. Resin constituents affecting reactivity, viscosity and curing agent compatibility can be quantified using HPLC with a chemically modified silica column which separates low molecular weight components. The analysis of four resins was tabulated: two standard BisA and BisA/F liquids and modifications of each: although the epoxide equivalent weights were the same after modification, both the latter had much lower viscosities and much better polyamide resin compatibility, overcoming the problem of excessively close induction time and pot life. Examples of solvent-free epoxy coatings on offshore structures were given.

Herr Klein looked briefly at epoxy novolacs, contrasting the performance of a new low viscosity, mixed isomer, non-crystallizing resin (XZ95345) with the higher viscosity standard DEN431 and DEN438. Cured with Ancamine 1618 the rate was faster (equivalent to a standard Bis A type) with no significant loss of epoxy novolac chemical resistance.

Finally, he discussed water-borne epoxy coatings, based on a new resin cured with lipophylic acrylic base polymer which is partially aminated and neutralized. A recommended basic formulation and method of manufacture was given. The pigmentation is incorporated into the aminated acrylic resin, which is cationic with a pH of 5 and will not tolerate basic pigments. The new low viscosity epoxy resin is not pigmented and is mixed in prior to use. The product has long pot life, excellent application characteristics, good flow and is reasonably quick drying, with the environmental advantages of non-flammability and aqueous clean-up. The problem of rust-rash formation when used on steel has not been solved and the resin system is recommended for coatings for mineral surfaces, wood and

galvanizing.

Projections of future sales indicate that conventional solvent-thinned epoxies will halve in volume 1984-1994, whereas solvent-free/high-solids and aqueous epoxies will increase by 50% and 20% respectively in the same period. Current research is addressing more tailor-made products and winter cure, whilst continuing to improve the various resins used.

After a short question period the vote of thanks was given by the Newcastle Section Chairman, Mr S. Lynn, and all adjourned to enjoy the normal excellent repast provided by St Mary's College.

J. Bravey ■

West Riding

Commercial decorative paints

The second Technical Meeting of this session was held at the Mansion Hotel, Roundhay, North Leeds, on Tuesday 18 October. The published lecture on marketing by Mr J. Hutchinson, Kalon Group PLC, had, regretfully, to be cancelled. We were very fortunate to secure, at short notice, an alternative lecture from Tioxide, entitled "Commercial Decorative Paints – A Performance Overview", presented by Brian Gregory from Tioxide, Stockton.

Brian Gregory's lecture could have been sub-titled, "There are more questions than answers". His appraisal of UK paints – Alkyd Liquid Gloss and Vinyl Silk – compared to European and Japanese counterparts must be considered, at least, thought provoking, at most perplexing. UK paint manufacturers' current aim of TiO₂ efficiency and/or reduction, and the various methods used, seems to pale in the light of Tioxide's appraisal of the Japanese achievements in glossy latex paints, i.e. unexpectedly high values of coverage from that achieved by UK paints at equivalent TiO₂ content. Tioxide's conclusions from the paint appraisals are detailed above.

NB. Flocculation gradient is a Tioxide method of determining TiO₂ efficiency.

Alkyd gloss paints

UK: Predominantly extender free, a high mean opacity and brightness and a clean tone. The lowest flocculation but the lowest mean TiO₂ content p.v.c.

EUR: Appreciable use of extenders, a lower mean opacity despite a higher mean TiO₂ content and p.v.c. compared to the UK: generally yellower paints with the levels of flocculation between the UK and Japanese. The European paint showed the widest property variations.

JAP: All the paints contained extenders. Comparable TiO₂ content to the UK paints, a high mean opacity and brightness. High total p.v.c.'s. High flocculation gradients (suspected to be influenced by the extenders present) and the yellowest tone. Overall less variation compared to UK and European.

Vinyl silk/gloss latex paints

UK: Wide range of TiO₂ content and p.v.c. and in the main extended. Lowest opacity, brightness and gloss. Flocculation gradient variation similar to Japanese, but less than the European. The bluest tone. These paints showed the widest performance variations, however they are used as wall paints, the European and Japanese products being used as gloss substitutes.

EUR: TiO₂ contents similar to the UK but lower than the Japanese glossy latex paints and with wider variation. Not extended, the European paints had intermediate opacity performance, lowest p.v.c.'s and superior gloss performance. They showed the widest flocculation gradient variation.

JAP: The highest and least variable TiO₂ contents and p.v.c.'s. The highest and most consistent brightness. Even taking into account the effects of TiO₂ content and flocculation, a number of the Japanese glossy emulsion paints exhibited significantly higher

OCCA Meetings

contrast ratios, (of the order of 2 full percentage points) than comparable UK and European counterparts.

The high brightness values achieved by these paints rule out the likelihood of toning additives. The Japanese glossy emulsions were mainly unfilled. Bead polymer type products were not detected, nor was there any apparent sign of opacity enhancement via increased dry film porosity (air void volume).

The question the lecture left hanging in the air was, "Have the Japanese paint technologists discovered an emulsion paint and binder system that contributes to dry opacity?" So far, Tioxide have not been able to discover the secret.

After some interesting questions, a vote of thanks was given by Rob Lewis, who made particular reference to Tioxide's rapid response to our need to fill the

sudden lecture gap, caused by the cancellation of the advertised lecture.

The formal part of the meeting ended, members and guest were then able to enjoy the usual West Riding free buffet and on this occasion the room we were using had an integral bar.

R. J. Lewis ■

OCCA News

West Riding Golf Trophy

Our members were beginning to think the West Riding Golf Trophy is always played on warm, sunny days. This year proved this not to be the case and it was somewhat difficult to make out the figures on the fairway in the mist and pouring rain. Many of the greens were covered in water but this did not prevent surprisingly high scores from some of our players.

Thirty members and guests braved the elements and were rewarded with a course in surprisingly good condition and a dryer finish to the round. Both the course and the club house facilities at Wetherby are very good and this doubtless accounts for the success of this event over the years.

The Cup was won by Roger Wells with 36 points, which was equalled by guest Jim Bury.

The day was rounded off with an excellent meal and the usual prize giving.

G. C. Alderson ■

News of Members

Dick Philbrick, immediate past Chairman of OCCA Natal, has been appointed Technical Director of Dekro Paints (Natal) (Pty) Ltd. He joined the paint industry in 1956 and trained as a paint technician with Sherwood Paints. After qualifying as a bench chemist he moved into production. He emigrated to South Africa in 1967



Dick Philbrick

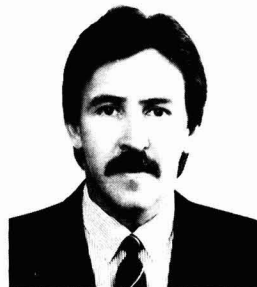
to join Plascon Paints in Luipaardsvlei as a factory chemist. Mr Philbrick has widened his experience as a development chemist and in technical sales at other factories. He joined Dekro Paints as Technical Manager in 1986. Mr Philbrick is married with five children. He notes his hobbies as motor rallying (now retired) and bridge.

R. Puterman ■

Regional appointment for Berger Paints Singapore MD

Edward B. Cowie, FTSC, Managing Director of Berger Paints Singapore, has been appointed Regional Director Far East for the London based Jenson & Nicholson Group, which owns Berger Paints. In his new role Mr Cowie will be responsible for the development of Berger's business in Singapore, Malaysia, Indonesia, Taiwan, Thailand and other countries in the region. Mr Cowie has 20 years' experience in the paint industry and was Chief Executive Officer of a

number of Berger Group companies in Africa and the Mediterranean before taking over as Managing Director of Berger Paints Singapore in 1987. Mr Cowie has recently been nominated as a Fellow of OCCA.



Edward Cowie

Professional grade

At the meeting of the Professional Grade Committee held on 12 October 1988 the following admissions were made:

Admitted to Associateship

Amand, Henri Gordon (Bristol)
Palmer, Michael (Thames Valley)
Patel, Rashmikant (Ontario)

New members

Ordinary members

Corner, T., BSc, PhD (London)
Moore, R., BSc, (West Riding)
Nanson, W. G. (West Riding)

Associate member

Marshall, H. P. (West Riding)

Registered Student

Zaheer, T. (General Overseas - Pakistan)

Professional Grade Register

List of successful candidates

As laid down in the report of the Working Party on Education, Training and Qualifications which was adopted on the institution of the Professional Grade, a list of those members in the Grade is published in the December issue of the *Journal* each year. The 17th such list appears below and includes the names of members resident in 35 countries.

The sections to which members are attached are given in italics.

Fellows

Addenbrooke, Brian John (*Midlands*)
 Anneveldt, Jan Johan Willem (*Transvaal*)
 Apperley, Thomas William James (*West Riding*)
 Arbuckle, Kenneth Harold (*London*)
 Archer, Harold (*Manchester*)
 Arnold, Michael Henry Miller (*London*)
 Ashworth, Norman (*Manchester*)
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 (E) – Editorial
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 (ON) – OCCA News
 (R) – Reviews
 (SC) – Short communications
 (T) – Transactions and communications

Subjects

	Page
A	
Acoustic emission investigation of zinc phosphate pretreatment of steel, An (T)	140
Acrylic urethane systems, Two pack (F)	413
Adhesion of a lacquer coating on the underfilm corrosion, An electrochemical investigation of the effect of the (T)	114
Adhesion of paints to metals, The effect of environmental conditions on the (T)	78
Adhesive manufacturer's viewpoint, An (F)	369
Aerosil fumed silicas (OM)	122
Aluminium organics (OM)	58
Amino Resins (OM)	145
Anti-corrosive primers free of lead and chromate, Some (T)	51
Anti-corrosion pigment, Calcium exchanged silica: A review (F)	257
Associative thickeners on coatings performance, The influence of, Part IV: Formulation surfactant effects (F)	315
Autoxidation of soya oil films, The use of deconvoluted fourier transform infra-red spectra to study the (T)	177
B	
Barium metaborate (L)	391
Basic wood science and decay control with surface coatings (OM)	59
Born to the purple (G, L)	144, 245
BS 5750 Organisation requirements for Quality Assurance (OM)	57
BS 5750 (E)	356
BS 5750 accreditation and beyond, Experiences on the road to (F)	366
BS 5750/ISO 9000 registration, Route to (F)	357
BS 5750 – The reality (F)	359
C	
Calcium exchanged silica anti-corrosion pigment; A review (F)	257
CAPCIS, Coatings technology (F)	165
CAPCIS (L)	245
Carbon black pigments (OM)	121
Cellulose paint thickeners, Liquefaction of (T)	34
Cellulosic paint thickeners, Liquefaction of, Part 2: Quantitative aspects of enzymatic degradation (T)	109
China clay as an extender (OM)	81
Chromate pigments for plastic and paints (OM)	215
Chromates lead: The state of the art in 1988 (T)	71
Coatings technology at CAPCIS (F)	165
Colour chemistry and dyeing at Leeds University – Services to Industry (F)	161
Colour difference measurements (OM)	21
Colour pigment failure – street name plate signs (L)	20
Colour space (L)	121
Colour, The future in (OM)	82
Commercial decorative paints (OM)	431
Concrete, Polymer emulsion based systems for the protection and repair of (F)	407
Concrete protection with methacrylate resins (F)	410
Concrete structures, Two pack epoxy coatings as protection for (F)	415
Confessions of a small paintmaker (OM)	59
Consultant in the Surface Coating Industry, The role of the (F)	173
Control of organic pigment dispersion (T)	7
Corrosion additives for solvent-bourne coatings (OM)	215
Corrosion protection of steel, The effect of the chemical composition of unpigmented organic coatings on the, Part 1: Preparation of novel coating resins (T)	241
Corrosion protection of steel, The effect of the chemical composition of unpigmented organic coatings on the, Part 2: Evaluation of heat-cured coatings made from the modified epoxy resins (T)	331
D	
Decorative paints (OM)	123
Development of novel driers (T)	17
Development of resins which give a high sagging limit for industrial applications, The (F)	204
Developments in fire protective coatings for military equipment: A review (T)	378
Disbondment characterization of polymer coating/metal substrate systems, Water (F)	276
DPP pigments (OM)	22
Driers, Development of novel (T)	17
E	
Effect of environmental conditions on the adhesion of paints to metals, The (T)	78
Effect of flocculation coatings, The (OM)	58
Effect of the chemical composition of unpigmented organic coatings on the corrosion protection of steel, The, Part 1: preparation of novel coating resins (T)	241
Effect of the chemical composition of unpigmented organic coatings on the corrosion protection of steel, The, Part 2: Evaluation of heat-cured coatings made from the modified epoxy resins (T)	331
Effect of water soluble contaminants at the steel/paint interface on the durability of the paint coatings, The (T)	11
Electrochemical investigation of the effect of the adhesion of a lacquer coating on the underfilm corrosion, An (T)	114
Emulsion based systems for the protection of repair of concrete, Polymer (F)	407
Emulsion paint binders, Recent advances in decorative (F)	201
Epoxy coatings as protection for concrete structures, Two pack (F)	415
Epoxy resins using liquid polysulphides, The modern approach to modifying (T)	39
Ernest Hughes? (L)	291
Experiences on the road to BS 5750 accreditation and beyond (F)	366
Exterior wood finishes (OM)	147
F	
Fire protective coatings for military equipment; Developments in: A review (T)	378
"First select your pigments" (OM)	180
Fulmer Yarsley – A broad range of services with the emphasis on problem solving (F)	159
Fundamentals in quality assurance (F)	373
G	
Glycol ether use in polyurethane coatings (T)	325
Glycol ethers for waterborne coatings, New propylene (T)	47
H	
High solids alkyd resins (R)	145
History and development of Mebon Paints (OM)	59

Index

I		R	
Industrial Solvents Handbook (R)	57	Recent advances in decorative emulsion paint binders (F) ...	201
Influence of associative thickeners on coatings performance. Part IV: Formulation surfactant effects, The (F)	315	Recent advances in manufacturing methods in the surface coating industry (OM)	146
Iron oxide pigment for use in anticorrosive coatings. A new synthetic process for the manufacture of lamellar (T)	132	Reliability of durability testing (L)	20
K		Requirements of coatings (F)	403
Karsten (L)	291	Resin developments at the Chemical Research Centre Shell Louvain-La-Neuve, Surface coatings (F)	196
Karsten, Lackrohstoff-Tubellen (R)	181	Resins for heat set and web offset printing processes (OM)	146
L		Resins which give a high sagging limit for industrial applications. The developments of (F)	204
Lead chromates: The state of the art in 1988 (T)	71	Role of an instrument maker in meeting quality control demand, The (F)	370
Leeds University - Services to Industry, colour chemistry and dyeing at (F)	161	Role of the consultant in the surface coatings industry, The (F)	173
Limitations of zinc phosphate as an inhibitive pigment, The (F)	273	Route to BS 5750/ISO 9000 registration (F)	357
Liquefaction of cellulosic paint thickeners. Part I: Degradative effects of redox and enzyme contamination (T)	34	S	
Liquefaction of cellulosic paint thickeners. Part 2: Quantitative aspects of enzymatic degradation (T)	109	Sagging limit for industrial applications, The development of resins which give a high (F)	204
M		Searching and the paint industry, On-line (F)	167
Maintenance painting of exterior timber (T)	419	Services at the PRA (F)	163
Matted coatings (OM)	21	Shell Louvain-La-Neuve, Surface coatings resin developments at the Chemical Research Centre (F)	196
Micro computers in the surface coating industries (OM)	83	Some anti-corrosive primers free of lead and chromate (T)	51
MIO (Micaceous Iron Oxide) paint for radiative cooling, Thermally emitting (T)	134	Some aspects of corrosion in the Durban harbour (OM)	392
Modern approach to modifying epoxy resins using liquid polysulphides, The (T)	39	Specifications in the paint industry (OM)	147
Moisture-curing one-pack polyurethane coatings - development, application (F)	208	Steel/paint interface on the durability of the paint coating, The effect of water soluble contaminants at the (T)	11
N		Surface coatings resin developments at the Chemical Research Centre Shell Louvain-La-Neuve (F)	196
New photoinitiator (OM)	81	Survey of Romano-British wallplaster, A (F)	417
New propylene glycol ethers for waterborne coatings (T)	47	T	
Newspaper inks (OM)	430	Technician's role in quality assurance, The, An aspect of modern paint technology (OM)	392
New synthetic process for the manufacture of lamellar iron oxide pigment for use in anticorrosive coatings, A (T)	132	Thermally emitting MIO (Micaceous Iron Oxide) paint for radiative cooling (T)	134
O		Timber, Maintenance paint of exterior (T)	419
On-line searching and the paint industry (F)	167	Tolerant coatings: In rust we trust (F)	103
Optical properties (R)	56	Two pack acrylic urethane systems (F)	413
Organic coatings science and technology Vol 8 (R)	57	Two pack epoxy coatings as protection for concrete structures (F)	415
P		U	
Phosphate as an inhibitive pigment, The limitations of zinc (F)	273	Use of deconvoluted fourier transform infra-red spectra to study the autoxidation of soya oil films, The (T)	177
Phosphate pigments, Water based protective coatings with (F)	97	W	
Phosphate pretreatment of steel, An acoustic emission investigation of zinc (T)	140	Water based industrial coatings (OM)	145
Pigment dispersion, Control of organic (T)	7	Water based protective coatings with phosphate pigments (F)	97
Polyurethane coatings, Glycol ether use in (T)	325	Water disbondment characterization of polymer coating/metal substrate systems (F)	276
Polyurethane coatings, Moisture-curing one-pack - development application (F)	208	Waxes (OM)	82
Polymer emulsion based systems for the protection and repair of concrete (F)	407	Who needs wetting agents? (F)	310
Powder coatings (T)	237	Wood science (OM)	392
PRA, Services at the (F)	163	A	
Pressure sensitive laminates (OM)	122	Page	
Printing half tone flexo (OM)	21	Algra, G. P., Erkens, L. J. H. and Kok, D. N., Lead chromates: The state of the art in 1988 (T)	71
Printing Ink Manual, The (R)	342	B	
Protective coatings (OM)	430	Bastidas, J. M., see Morcillo, M. (T)	11
Protective coatings - Has the surface coating industry risen to the present challenge? (E)	86	Berber, M., see Orel, B. (T)	134
Protective coatings in the process and food industries (F)	105	Bittner, A., Water based protective coatings with phosphate pigments (F)	97
Q		B	
Qualitative assessment of recent upheavals in the paint industry - where will we all be in 1993 (OM)	391	Page	
Quality assurance, Fundamentals in (F)	373	A	
Quality control demand, The role of an instrument maker in meeting (F)	370	Page	

Index

Boxall, J., Maintenance painting of exterior timber (T)	419	McKay, R. B., Control of organic pigment dispersion (T) ...	7
Breakell, J., CAPCIS (L)	245	McLaren, K., Colour space (L)	121
Breakell, J. E., Coatings technology at CAPCIS (F)	165	Morcillo, M., Feliu, S., Galvan, J. C. and Bastidas, J. M., Effect of water soluble contaminants at the steel/paint interface on the durability of the paint coating, The (T)	11
Brooks, S., Experiences on the road to BS 5750 accreditation and beyond (F)	366	391
Burkill, J. A. and Mayne, J. E. O., Limitations of zinc phosphate as an inhibitive pigment, The (F)	273	Morgan, D. E., Barium Metaborate (L)	417
C			
Carter, E., New synthetic process for the manufacture of lamellar iron oxide pigment for use in anticorrosive coatings, A (T)	132	Morgan, G. C., Survey of Romano-British wallplaster, A (F)	167
Cooney, B. J., Mrs., Ernest Hughes? (L)	291	Morgan, N. R., On-line searching and the paint industry (F)	415
Cowley, A. C. D., and Gallon, M. R., Who needs wetting agents? (F)	310	Moss, N. S., Two pack epoxy coatings as protection for concrete structures (F)	20
Crnjak, Z., see Orel, B. (T)	134	Moulton, D. V., Reliability of durability testing (L)	315
D			
Dasgupta, D., Services at the PRA (F)	163	N	
E			
Easy, R., Route to BS 5750/ISO 9000 registration (F)	357	Newton, G. P., Fulmer Yarsley - A broad range of services with the emphasis on problem solving (F)	159
Erkens, L. J. H., see Algra, G. P. (T)	71	O	
F			
Feliu, S., see Morcillo, M. (T)	11	O'Hara, K., Two pack acrylic urethane systems (F)	413
Fernando, R. H., see Murakami, T. (F)	315	Orel, B., Crnjak, Z., Radoczy, I., Knific, F., Berber, M. and Rejec, I., Thermally emitting MIO (Micaceous Iron Oxide) paint for radiative cooling (T)	134
G			
Gad, H. A., see Goma, A. Z. (T)	51	R	
Gallon, M. R., see Cowley, A. C. D. (F)	310	Radoczy, I., see Orel, B. (T)	134
Galvan, J. C., see Morcillo, M. (T)	11	Rawlings, R. D., see Roum, J. (T)	140
Glass, J. E., see Murakami, T. (F)	315	Rees, T. M., Thompson, N., and Willford, A., Modern approach to modifying epoxy resins using liquid polysulphides, The (T)	39
Goldie, B. P. F., Calcium exchanged silica anti-corrosion pigment: A review (F)	257	Rejec, I., see Orel, B. (T)	134
Goma, A. Z., and Gad, H. A., Some anti-corrosive primers free of lead and chromate (T)	51	Robery, P. C., Requirements of Coatings (F)	403
Gowers, K. R., see Jin, X. H. (T)	78	Roum, J. and Rawlings, R. D., Acoustic emission investigation of zinc phosphate pretreatment of steel, An (T)	140
Gowers, K. R., and Scantlebury, J. D., Electrochemical investigation of the effect of the adhesion of a laquer coating on the underfilm corrosion, An (T)	114	Routs, A., Role of an instrument maker in meeting quality control demand (F)	370
Guthrie, J. T., Colour chemistry and dyeing at Leeds University - Services to Industry (F)	161	Russell, G. C. R. and van Westrenen, W. J., Surface coatings resin developments at the Chemical Research Centre Shell, Louvain-La-Neuve (F)	196
H			
Hamblin, R., Born to the purple (G, L)	144, 245	S	
Hamburg, H. R., Role of the consultant in the surface coatings industry, The (F)	173	Sattler, E., Concrete protection with methacrylate resins (F)	410
Heckman, R. A., Glycol ether use in polyurethane coatings (T)	325	Sandland, R., Adhesive manufacturer's viewpoint, An (F)	369
Hoppe, M., Powder coatings (T)	237	Scantlebury, J. D., see Gowers, K. R. (T)	114
Hutchinson, G. H., Printing Ink Manual, The (R)	342	Scantlebury, J. D., see Jin, X. H. (T)	78
J			
Jin, X. H., Gowers, K. R. and Scantlebury, J. D., Effect of environmental conditions on the adhesion of paints to metals, The (T)	78	Smith, K. R., BS 5750 - The reality (F)	359
Jolly, V. G., Karsten (L)	291	Spadafora, S. J. and Leidheiser, Jr., H., Water disbondment characterization of polymer coating/metal substrate systems (F)	276
Jones, P. B., Polymer emulsion based systems for the protection and repair of concrete (F)	407	Spauwen, J., New propylene glycol ethers for waterborne coatings (T)	47
K			
Knific, F., see Orel, B. (T)	134	Springle, W. R., Liquefaction of cellulosic paint thickeners. Part 1: Degradative effects of redox and enzyme contamination (T)	34
Kok, D. M., see Algra, G. P. (T)	71	Springle, W. R., Liquefaction of cellulosic paint thickeners. Part 2: Quantitative aspects of enzymatic degradation (T)	109
Kubitza, W., Moisture-curing one-pack polyurethane coatings - development, application (F)	208	T	
L			
Lea, B. E., Colour pigment failure - street name plate signs (L)	20	Thompson, N., see Rees, T. M. (T)	39
Leidheiser, Jr., H., see Spadafora, S. J. (F)	276	U	
M			
Mayne, J. E. O., see Burkill, J. A. (F)	273	Usman, N., Development of novel driers (T)	17
V			
Vaes, E. H. M., Use of deconvoluted fourier transform infra-red spectra to study the autoxidation of soya oil films, The (T)	177		

Index

van Westrenen, W. J., see Russell, G. C. R. (F)	196
Vijverberg, C. A. M., Development of resins which give a high sagging limit for industrial application. The (F)	204
W	
Wake, L. V., Developments in fire protective coatings for military equipment: A review (T)	378
Wallace, D. M., Fundamentals in quality assurance (F)	373
Ware, J. E., BS 5750 (E)	356
Widdop, B. L., Recent advances in decorative emulsion paint binders (F)	201
Wilford, A., see Rees, T. M. (T)	39
Williams-Wynn, D. E. A., Effect of the chemical composition of unpigmented organic coatings on the corrosion protection of steel. The. Part I: Preparation of novel coating resins (T)	241
Williams-Wynn, D. E. A., Effect of the chemical composition of unpigmented organic coatings on the corrosion protection of steel. The. Part 2: Evaluation of heat-control coatings made from the modified epoxy resins (T)	351
Windsor, B., Tolerant coatings: In rust we trust (F)	103
Withers, A., Protective coatings in the process and food industries (F)	105

Association events and news

C	
Chester Conference (ON)	23, 61, 148, 183, 246, 290, 296, 345, 346, 395
Company Visits	
— BASF Graphics, Cheadle Hulme (N)	122
— Tour of Tioxide, Calais (N)	180

Conference discussions, OCCA 1987 (ON)	55-56
--	-------

J

Jordan Award (ON)	390
-------------------------	-----

N

New Members (E)	61, 85, 124, 184, 217, 246, 345, 432
News of Members	
— R. H. Hamblin (ON)	83, 295
— D. House (ON)	215
— D. Philbrick (ON)	???
— E. B. Cowie (ON)	???

O

Obituary	
— D. J. Pienaar (ON)	25
— D. S. Newton (ON)	26
— R. C. Somerville (ON)	124
— L. Valentine (ON)	148
— K. Hedgecock (ON)	148
— G. A. Campbell (ON)	216
— H. Gosling (ON)	393/4

P

Proceedings of the Annual General Meeting (ON)	293/5
Professional Grade (ON)	85, 184, 345, 432

R

Report of Council Meeting (ON)	83, 182, 292
--------------------------------------	--------------

S

SURFEX 88 Official Guide (F)	between 136-137
SURFEX 88 Review (F)	218, 224
SURFEX 88 Update (G)	between 73-74

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INDEX TO ADVERTISERS

	Page
C	
Concrete Society	411
Cornelius Chemical Co Ltd	411
M	
Morton Thiokol Ltd	Back Cover
N	
NL Chemicals Ltd	Inside Front Cover
R	
Rohm & Haas Ltd	424

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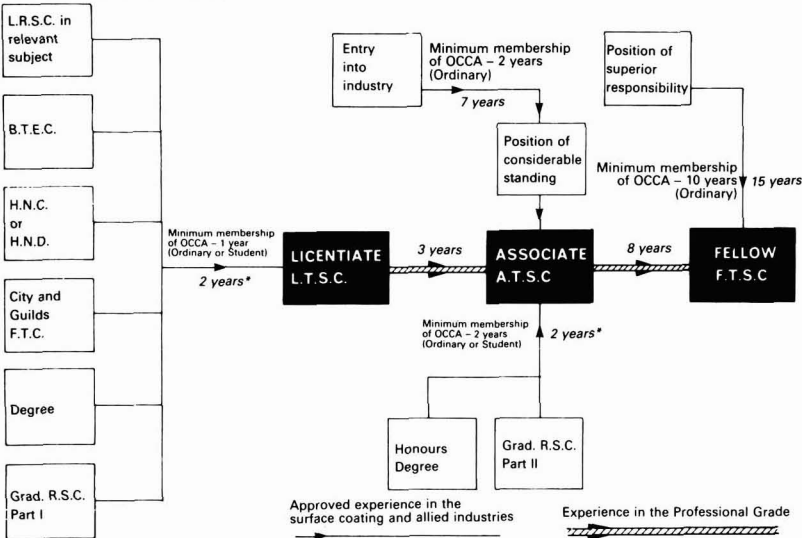
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