JOINING COMPOSITE STRUCTURES

Gareth C McGrath

Adhesive Technology Coordinator, TWI, Abington Hall, Abington, Cambridge, CB1, 6AL, UK

Synopsis : *The excellent performance record which has been established by composites over the last 30-40 years is acknowledged by an ever-increasing commitment to the creation of ever larger structures which must function effectively for prolonged periods. Adhesive bonding is one method which can be used to assemble the parts and it is known to be very successful. However,in a world where production costs are forever under pressure it is essential to know the limiting parameters eg.surface treatments and adhesive selection. The paper discusses basic issues such as these in relation to bonding pultrusions.*

INTRODUCTION

The structures involved are varied and rnay range from ladders and walkways to marine structures - including offshore platforms. A multitude of individual matrix resins is used which can be divided into the following major categories.

- Polyamide (Nylon)
- Epoxide
- Polyphenylene oxide
- Phenolic
- Polypropylene
- Polyurethane

Moulded parts are likely to be contaminated by mould release agent which is not exactly the best base for long term adhesive bonding. Such release agents may be used either directly in the mould while others may be 'self - releasing' formulations.

The composite rnay be bonded to other materials such as :

- Aluminum
- Steel
- Zinc
- Paint
- Another composite

Of the many paints that rnight be used only the electro deposited cataphoretic paints applied to properly prepared surfaces are likely to provide a sufficiently stable base for structural bonding.

MATERIAL SELECTION

Of the many adhesive types, five groups are candidates for compcsite bonding. Two of these (phenolic and polyamide) tend to be used on very specialised work and for the majority of applications, three major groups dominate :

- epoxy - one part and two part,
- acrylic - one part, and two part,
- polyurethane -one part and two part.

ADHESIVES

Epoxies

There is no doubt that these adhesives in their heat cured, single part form are extremely durable. For example, they have been used to assemble heat exchangers fabricated from a glass-filled nylon composite and aluminium tubes. There have never been any failures despite the fact that the joints have

Contd..... Page 31

INTERNATIONAL WELDING CONFERENCE

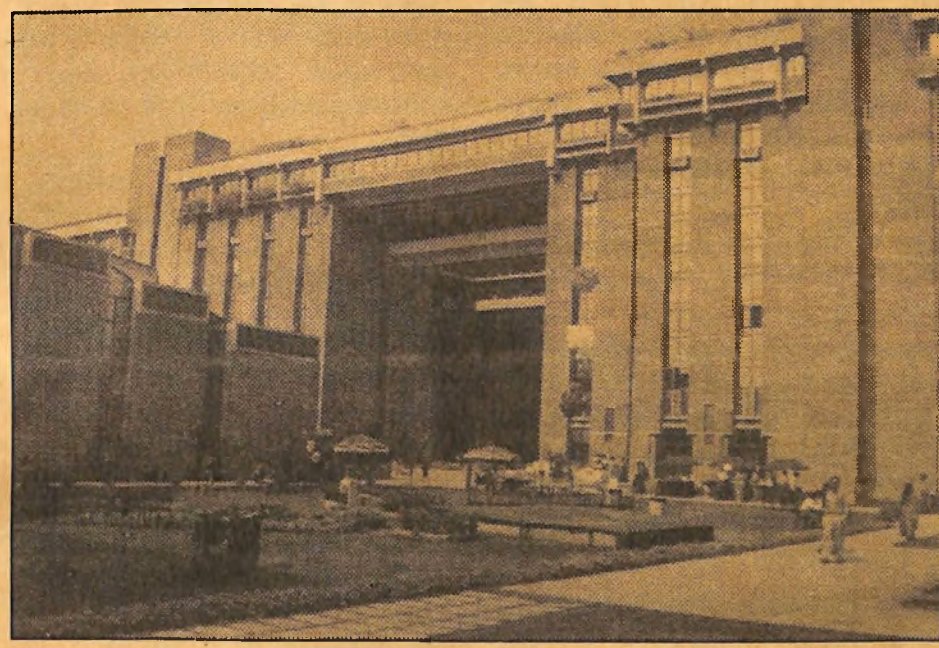
(IWC – 2001)

ON

ADVANCES IN WELDING AND CUTTING TECHNOLOGY

Conference Venue : IHC Auditorium, Habitat World, Lodi Road, New Delhi 110 003, INDIA

15–17 February, 2001 New Delhi, India



Please contact :

For Registration

Mr. J. C. Shahani
Organising Secretary &
Chairman – Registration Committee
The Indian Institute of Welding
3A, Loudon Street,
Calcutta 700 017, INDIA
Phone : 91-33-281 3208
Fax : 91-33-240 1350
E-mail : indianwelding@vsnl.net

For General Information

Mr. S. M. Mahajan
Joint Organising Secretary
Additional General Manager
Corporate Office,
Bharat Heavy Electricals Limited
Siri Fort, New Delhi 110 049 India
Phone : 91-11-600 1054 / 600 1010 Ext. 2577
Fax : 91-11-600 1054 / 649 2534
E-mail : cmtsmm@asiad.bhel.com.in

Organised by

THE INDIAN INSTITUTE OF WELDING

in association with

Confederation of Indian Industry

INTRODUCTION

The Indian economy is on the revival path and the industrial growth is predicted to reach 8% by the end of the fiscal year. The automobile sector has already registered over 40% growth. This industrial scenario presents a very bright future for the industry. As welding is an inseparable part of the manufacturing sector, the welding industry is also poised for a vibrant growth. While this scenario is encouraging, the industry is also likely to face fierce national and global competition and may have to adopt excellent marketing skills and business strategies to survive the competition. Further, the importance of information technology and need to develop high quality products based on co-operative research amongst the industry and research institutions cannot be overlooked.

In this backdrop, marketing of new products and processes by the welding industry and presentation of work by research and academic institutions to the user industries is essential. In other words, exchange of information on the latest developments on welding processes, equipment, consumables and methods has become imperative to the industry. The International Welding Conference IWC-2001 provides the right opportunity and forum to fulfil this objective.

CONFERENCE PROGRAMME

The International Conference on Welding & Cutting Technology is to be held in February 2001. The 3-day Conference will be spread out to several technical sessions covering various areas of joining of metals as well as non-metals. The objective of this Conference is to assess the present trends in the various facets of welding science and technology in the national and international scene. The Conference will focus the changes and advances in Welding Technology in the basic and applied research, fabrication of critical plant and equipment, pipe lines, weld automation and Robotics, development of specialised welding consumables for critical applications in various core sector of industries such as power, oil, steel, cement, petrochemical, fertiliser, etc. The new developments in the field of welding process, metallurgy and welding equipment will also be the highlight of the Conference. In addition to the main conference for which the papers are being invited a concurrent Poster Session will also be held at the venue.

WHO SHOULD ATTEND

Engineers and technical management personnel engaged in design, construction, repair and operation in the oil and gas power generation, petrochemicals, pipeline, structural engineering, railways, automobiles, heavy engineering, pressure vessel, earth moving equipment, ferrous and non-ferrous manufacturing, shipbuilding, aerospace aviation and defence industries. Chief Executives, Technical Experts, Engineers and Managers from organisations engaged in the manufacture of welding equipment and allied machineries, consumables, safety and pollution monitoring equipment and others are expected to attend.

Personnel from Welding Institutes, Associations, Professionals and Students will also find the Conference of great importance. All deliberations will be in English language.

REGISTRATION OF DELEGATES

For registration, please send details as per format of Reply Form, duly filled in, along with the requisite delegate fee applicable as per details under "Delegate Fee & Registration".

For further details, please contact :

Mr. J. C. Shahani
Organising Secretary - IWC 2001
Chairman – Registration Committee
The Indian Institute of Welding
3A, Loudon Street, Calcutta 700 017, INDIA
Phone : 91-33-281 3208 Fax : 91-33-2401350
E-mail : indianwelding@vsnl.net

For General Information :

Mr. S. M. Mahajan
Joint Organising Secretary - IWC 2001
Additional General Manager
Corporate Office,
Bharat Heavy Electricals Limited
Siri Fort, New Delhi 110 049
Phone : 91-11-600 1054 / 600 1010 Ext. 2577
Fax : 91-11-600 1054 / 649 2534
E-mail : cmtsmm@asiad.bhel.com.in

PRESENTATION OF TECHNICAL PAPERS : Guidelines

Technical papers are invited from the distinguished speakers from India and abroad engaged in the field

of research, fabrication, repair and reclamation, Qualification and Certification, Quality Control, Non-destructive Examination, Safety and Education to present state of art of the Welding and Allied Technology.

A synopsis of the technical paper may be submitted in advance. Full paper along with a passport size photograph and brief bio-data of the speaker should reach

Mr. S. Samidas
Chairman, Technical Committee - IWC 2001
C/o. Welding Research Institute,
Bharat Heavy Electricals Limited
Tiruchirapalli – 620 014, INDIA
Phone : 91-431-520 244
Fax : 91-431-520 554
E-mail : wrisamidas@bheltry.co.in

Last date of Submission of Full Paper :

End November 2000

CONFERENCE SOUVENIR & ADVERTISEMENTS

On the occasion of International Welding Conference, a Souvenir will be published containing the programme of the Conference, Technical papers to be presented, other relevant informations and advertisements. Advertisers are requested to make a note of the advertisement rates mentioned and book their advertisement in the format for Reply Form as early as possible and send the matter in the form of Typed matter, Camera ready Artwork with a crossed Cheque or Demand Draft in favour of "The Indian Institute of Welding", payable at Calcutta and send the same to

Mr. M. P. Dhanuka
Chairman,
Advertising Committee, IWC 2001,
The Indian Institute of Welding,
3A, Loudon Street, Calcutta 700 017.
Phone : 91–22–6528545/8380
Fax : 91–22–652 6544
E-mail : mpdhanuka@adorians.com

WELD INDIA INTERNATIONAL - EXHIBITION

The Second International Exhibition, WELD INDIA INTERNATIONAL EXHIBITION 2001 is also being organised jointly with Confederation of Indian Industry (CII) from 15th to 19th February 2001 at Pragati Maidan, New Delhi, India

FORMAT FOR REPLY FORM

The Organising Secretary
The Indian Institute of Welding
3A, Loudon Street, 4th Floor,
Calcutta 700 017
INDIA

INTERNATIONAL CONFERENCE ON ADVANCES IN WELDING AND CUTTING TECHNOLOGY
15 – 17 February 2001 : New Delhi, INDIA

Our Organisation will be represented by:

Name(s) Designation

1. _____

2. _____

3. _____

A Draft for Rs. _____ (US$ _____) towards delegate fee, drawn in favour of **"THE INDIAN INSTITUTE OF WELDING – IWC 2001"** payable at Calcutta is enclosed / will follow.

. . . . . .

Please book the following Advertisement Space(s) in the Souvenir of INTERNATIONAL WELDING CONFERENCE-IWC 2001 during 15 – 17 February 2001, New Delhi, INDIA.

Position	
Rate	

A Cheque/Draft for Rs. _____ (US$ _____) towards Advertisement space, drawn in favour of **"THE INDIAN INSTITUTE OF WELDING – IWC 2001"** payable at Calcutta is enclosed / will follow.

Signature:

Name & Designation:

Organisation:

Address:

Phones :

Fax :

Date :

(Please Note : Cheques/DD on Calcutta Bank shall be preferred. For outstation cheques, if any, please add Rs. 100/- as processing charges. and for overseas cheques please add bank charges as appilicable)

Weld India International 2001 - Exhibition is the concurrent show alongside the major International Exhibition in India – INDIA EXPO 2001 (14th IETF).

For detailed information about the Exhibition and booking of space, please contact :

Ms. Satya Girijan, Executive Officer
Confederation of Indian Industry
Gate No. 31, North Block
Jawaharlal Nehru Stadium, New Delhi - 110 003
Phone : 91-11-436 6225 / 6273 to 6276
Fax : 91-11-436 6271 / 7844
E-mail : tsg@sai.cii.ernet.in
Website : www.ciionline.org

NEW DELHI – CLIMATE IN FEBRUARY

New Delhi – the capital of India will be moderately cool and dry in the month of February with the temperature ranging between 10°C and 28°C. There are many sight seeing places in and around New Delhi. The organiser would arrange sight-seeing tour programme on request.

DELEGATE FEE & REGISTRATION

	Till Nov 2000	After Nov 2000
Members of IIW & CII	Rs. 4000	Rs. 5000
Non-Members	Rs. 5000	Rs. 6000
Overseas Delegates	US$ 400	US$ 500
Senior Citizens, SSI Units, Educational Institution, (who are members of IIW)	Rs. 2500	Rs. 3000

ADVERTISEMENT RATES

FRONT COVER OUTSIDE	Rs. 50,000
FRONT COVER INSIDE	Rs. 20,000
BACK COVER OUTSIDE	Rs. 30,000
BACK COVER INSIDE	Rs. 20,000
INSIDE COLOUR PAGE (Art Paper)	Rs. 8,000
PULLOUT 2 PAGES	Rs. 15,000
FULL PAGE (B/W)	Rs. 5,000
BOOK MARKER (2 nos.)	Rs. 8,000 each
EDGE STRIPE	Rs. 6,000

been exposed to a hot 25% glycol solution for many years. Two part epoxies are also of good durability as proved by their use in the vehicle and shipbuilding industries.

Acrylics

The basic form of the acrylic adhesive is far too stiff and brittle to be considered useful for structural purposes. Consequently, it is toughened with a variety of rubbery additives.

A study produced by the Admiralty (AMTE (M) TM 79307) has demonstrated that these adhesives outperformed the polyester composites that they were used to assemble. As a consequence, they have been extensively used for the bonding of composite and aluminium components in ocean-going ships.

Polyurethanes

The polyurethanes have a particular problem - they are sensitive to chemical attack by water - especially when warm and particularly in the presence of metal or metal oxide, when some form of catalytic degenerative process also appears to take place. Therefore, polyurethanes must not be used directly upon metal surfaces without a thorough analysis of the expected conditions during use.

The compatibility of various materials with these adhesives is discussed later. The adhesives are summarised in Table I.

ADHERENDS

Metal

Both the heat cured epoxides and the toughened acrylic type will bond oil contaminated metal surfaces very successfully. However, safety critical, loaded joints must be properly prepared to guarantee a long, durable performance.

Aluminium bonds well with the epoxies and particularly well with acrylic adhesives. Maximum durability requires either silane, phosphate or chrome passivation treatments.

Steel requires the use of either silane or Accomet C treatments for maximum durability.

Zinc is a weak, readily oxidised metal that behaves badly unless properly prepared and designed. Both Accomet C and chrome passivation give bonded joints of excellent durability though if these are to be loaded, low modulus adhesives should be used. (Note: polyurethanes need a separate primer coating).

Thermoplastics

Polyamide (Nylon) will bond poorly unless hot or pre-treated by grit blasting, oxidation or corona discharge. When hot bonding it is necessary to consider the release of absorbed moisture. Stress cracking can be a problem and it is neceesary to be aware of this

Polypropylene requires an effective surface preparation such as grit blasting although it is better to use oxidation, corona discharge, or a chlorinated primer.

Thermoset

Epoxy matrix composites are usually used for only the most demanding circumstances and consequently are bonded with either the two part or single part epoxies . When the latter are used care should be taken to ensure that absorbed water is released. While the acrylics and polyurethanes can bond them well, the lower moduli of these adhesives generally makes them unsuitable for the type of application involved.

Phenolic bonds very well with epoxies, (it is necessary to ensure absorbed water is released if heat cured versions are used) but some types do not suit all acrylics and polyurethanes quite as well. However, a point worth noting is that the polyurethanes can release toxic (–CN) fumes on burning. As phenolic composites are normally used because of low smoke and fume emission when burnt, the use of a polyurethane to bond them is questionable.

Polyester will bond well with all types of adhesive but single part epoxies are not normally used because of the higher curing temperatures required. If single part epoxies are used then care should be taken over the release of absorbed water. Surface preparation needs very careful consideration.

Table 1 : Characteristics of the principal structural adhesives for composite bonding.

	Main Features	Principal advantages	Principal disadvantages
One part polyurethane	Low modulus. Very low strength	Very simple to use. Hot melt variants very convenient on suitably sized components. Fills large gaps. No mixing.	Sensitive to moisture. Not true structural adhesives. Slow cure. Must be applied to non-metal surface for durability.
Two part polyurethane	Very low to medium modulus. Very Low to medium strength	Fast curing possible. Very good application characteristics. Fills large gaps.	Sensitive to moisture. Often requires heating to achieve acceptable production times. Must be applied on a non-metallic surface for durability. Some versions are not structural. Must be mixed.
One part acrylic	Medium modulus Medium strength	Very fast. Very easy to apply. Extremely durable. Bonds metal particularly well. Copes with contamination well. Structural adhesive. No mixing.	Needs good fit and narrow gaps to function effectively. Best below 1mm gap
Two part acrylic (VOX)	Medium modulus Medium strength	Fast. Easy to apply. Benefit of delayed action cure. Extremely durable. Fills large gaps. Copes well with light contamination. Structural adhesive.	Must be mixed.
One part Epoxy	High modulus Very high strength	Fast curing. Easy to apply. Extremely durable with robust all round performance. No mixing.	Needs to be heat cured.
Two part Epoxy	Medium to high modulus. Medium to high strength	Easy to apply. Durable. Can be speeded by heating. Structural adhesive..	Must be mixed. Slow curing.

Polyurethane (RIM) bonds particularly well with polyurethane adhesives and, selectively, with epoxies and acrylics.

Paint

Cataphoretic paints are probably the only paint material with sufficient integrity to be used as a base for structural bonding. Even then, the underlying surface will need proper preparation if the paint is to function properly. Paint, or speciality primer, needs to be used to ensure the chemical stability of polyurethane adhesive on metal.

Table 2 presents a broad impression of the compatibility of a number of composite materials with the adhesives generally considered to be suitable for their structural assembly. Also included, are other materials often used in association with composites. The information

Table 2 : Compatibility of the principal structural adhesives with a variety of composite and associated materials.

Acrylic	Epoxy				PU
Material to be Joined	One Part	Two Part	One Part	Two Part	Two Part
Metal (Also see paint)					
Aluminium	V Good	V Good	V Good	V Good	Poor
Steel	V Good	V Good	V Good	V Good	Poor
Zinc	Good	Good	Good	Good	Poor
Thermoset					
Epoxy	Good	Good	V Good	V Good	Good
Phenolic	Good	Good	V Good	V Good	Good
Polyester	V Good	V Good	Good	V Good	V Good
Polyurethane - RIM	Fair	Fair	Poor	Good	V Good
Thermoplastic					
Polyamide (Nylon)	Good	Good	Poor	Good	Good
Polyphenylene oxide	Fair	Fair	Fair	Good	V Good
Polypropylene	Good	Good	Poor	Fair	Good
Paint					
Cataphoretic	V Good	V Good	V Good	V Good	V Good

given should be interpreted carefully in the light of the previous observations.

DESIGN

There is benefit to be gained by designing a component in such a way that the adhesive will be supported by the part's geometry rather than being undermined by it. This is achieved by designing the joint so that the forces experienced tend only to compress the adhesive or induce, if possible, both compression and shear loads. If this cannot be done the design should induce the unwanted cleavage forces away from the vulnerable edge of the joint, see Fig. 1.

The ultimate performnance may be gained by bonding such panel section into either an aluminum extrusion or into a pultrusion. Joints such as these, based on the concepts of Fig. 2, are virtually indestructible given an appropriate insert length.

The designer's choice of material, its preparation for production bonding and that latter process itself are limited by the reaction chemistry of the main family types and the durability of the end product of that reaction. Durability is the key and its achievement a controlling factor.

PRODUCTION

Effective production requires the creation of a defined product within specification at minimum cost. Given that such cost influencing issues as design, compatibility and long term durability have been resolved, then for a large structure the final considerations are :

- Ease of use
- The cost incurred if mixing is needed
- The cost of surface preparation
- The practicality of surface preparation

Surface preparation

The surface thermo-dynamics of thermoset composite materials favour the bonding process and were it not for the need to remove the mould release agent and contaminants there would be no need for surface preparation prior to bonding.

Mould release agents do not form a good base for adhesive bonding and the usual practice is to remove them either by very light abrasion, followed by a solvent wash, or to overcome their effects by treatment with chemically active primers.

Thermoplastic composites are not generally so favourable and bonding may prove difficult unless the plastic concerned is treated in some way. This may range from grit blasting to

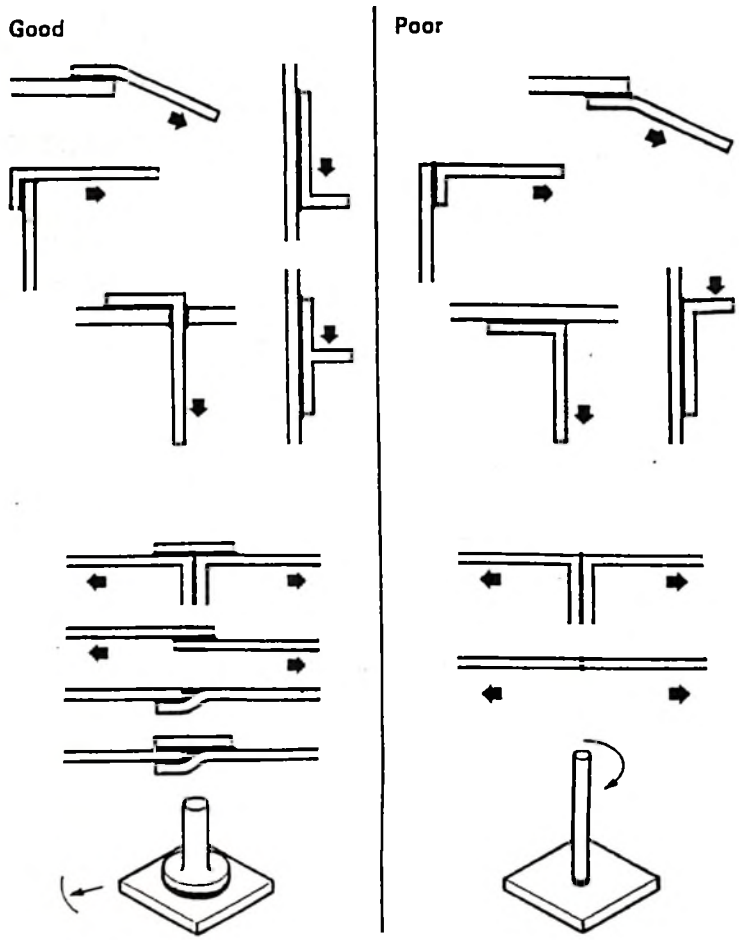


Fig. 1 : Design principles for adhesively bonded joints

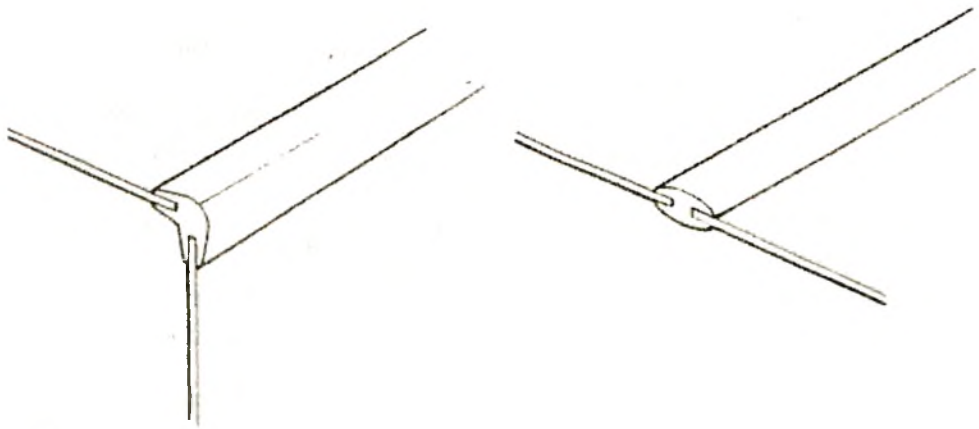


Fig. 2 : Alternative versions of a contained joint based on pultrusions

oxidation, through corona discharge, to the use of the chlorinated polyolefin primers which are now being introduced for the bonding of polypropylene based composites.

Mixing and application

The issues involved are perhaps best examined by considering two extremes. At one end of the scale stands the motor vehicle automated component assembly line while at the other end is the steady but slow assembly of a ship's panel work in an ever changing environment. This latter situation does not lend itself to major capitalization except under exceptional circumstances. Yet, the quality demands on the workforce are much higher simply because of their circumstances and an environment which is much harder to control.

The assembly of large, awkward panels high above the ground requires simple, light equipment which will function well despite variable temperatures. Yet while the adhesive needs slump resistance, it will also need to be mixed and dispensed easily.

These contradictory requirements may be resolved by the provision of correctly formulated materials which can be mixed at pre-determined temperatures by a fixed location mixer/dispenser which fills re-usable cartridges to be distributed on demand to the assembly team. This system also has the advantaqe that air is not incorporated into the mixed adhesive as it would be if hand mixing and spreading were employed.

As assembly conditions become progressively less arduous and demanding of the workforce, cartridge guns incorporating static mixers can be used directly. These have improved considerably recently and better designs have given the adhesive manufacturers greater scope for versatility.

Process control

When an adhesive is used on-site, the process control is vital because once the joint has been made it is very difficult to inspect and therefore adhesive bonding should not be regarded as deskilling. Therefore, the production of large bonded composite structures requires very careful process control, by skilled operators.

CONCLUSION

Large composite structures, particularly those based on thermoset resins can be readily and durably bonded, both to themselves and associated metal structures. ■

CONSTITUTION OF TASK FORCES

It has been decided by the Council of the Institute, to constitute the following groups with appointed Chairmen for formulating suitable framework of activity, thus :-

1. **'Securing Government Recognition of AMIIW Exam'** Task Force – Chairman : Dr. S. R. Gollapudi (Tel: 0891-815352 Fax: 815399 E-mail: subbarao@md3.vsnl.net.in)
2. **'Accreditation as ANB & ATB'** Task Force; for Authorised National Body & Authorised Training Body – Chairman : Mr. A. C. Lahiri (Tel: 033-2455024 Fax: 2441308)
3. **'IIW Website Development'** Task Force – Chairman : Mr. S. K. De (Tel: 033-4243683 Fax: 4242242 E-mail: soumitrakde@hotmail.com)
4. **'Review of Branch Rules'** Task Force – Chairman : Mr. N. K. Sarkar (Tel: 022-7668480 E-mail : tranik@bom8.vsnl.net.in)

All interested members of the Institute are invited to contact the above to contribute their suggestions, with copy to HQ Secretariat for co-ordination/assistance

– J. C. Shahani
Honorary Secretary,
IIW Council