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Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
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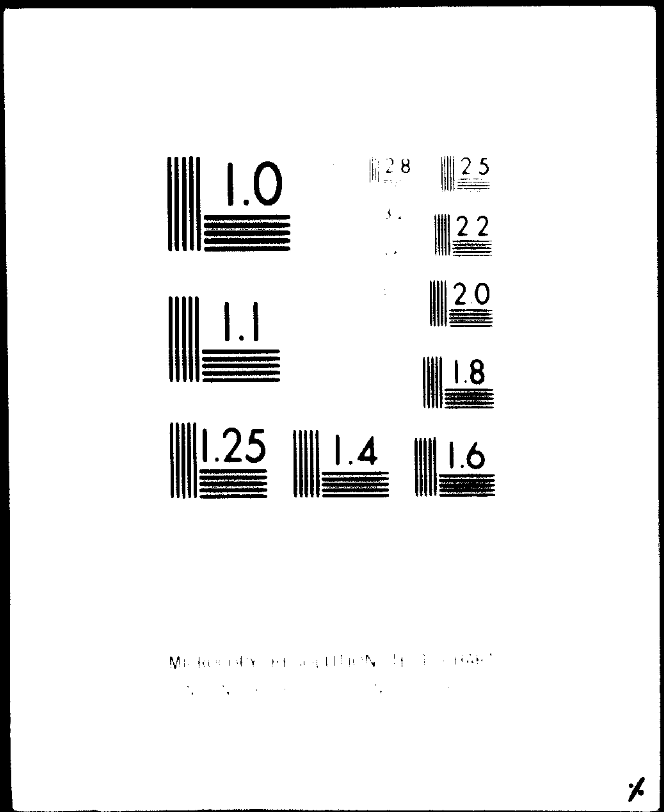

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WORKING PAPER

THE PAST, PRESENT AND FUTURE OF PLASTICS IN BUILDING APPLICATIONS

by

O P RATRA

UNIDO CONSULTANT and Project Co-ordinator

PLASTICS IN BUILDING PROGRAMME

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<u>THE PAST, PRESENT, AND FUTURE OF PLASTICS IN BUILDING APPLICATIONS</u>

by O P Ratra *

<u>INTRODUCTION</u>

The universal call for provision of large number of buildings of all types i.e for houses, hospitals, schools, factories, and others of commercial and public utilities, at comparatively faster rate and lower cost necessitated systematic research and development of new building materials and construction techniques. Mass-housing, prefabrication, and industrialised building systems are the familiar terms coined to attend to this universal call. According to one UN estimate, between 1,100 million and 1,400 million new dwellings must be constructed in the world before the end of this century. Assuming a medium estimate of 1,250 million, an average annual output of more than 40 million new dwellings are required, almost 10 million in the more developed areas. In the light of this massive requirement and with the current concepts of design and construction towards performance orientation, the need to organise studies in the manufacture and judicious use of building materials through locally available resources has been emphasized at several international meetings. The introduction of new materials and assessing their technical suitability for building applications to meet the local requirements has attained even greater significance both in developed and developing countries. The traditional materials and techniques invariably fall short of their performance under conditions of use. Advances in materials technology range from modestto exotic. Some are already in use others appear to be promising for the near future, still others are

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* UNIDO Consultant

in development for introduction in the distant future. Among these are plastics - the synthetic organic materials. During the past thirty five years plastics have invaded practically every field of human activity. And today plastics are next only to metals in the per-capita consumption of materials. The growth of world plastics industry has been enormous, from little over 3 million tonnes in 1955 to over 40 million tonnes in 1975. The estimates for 1980 are to attain a production level of 90 million tonnes.

THE THEME OF THE SEMINAR :

The theme of today's Seminar is To Build With Plastics :

- for upgrading the utilities and services in the building industry,
- for providing economically and socially acceptable 'shelter' for the slum dwellers,
- for providing 'Emergency Housing' in times of natural disasters, and
- for meeting the demand for provision of basic housing keeping in view the local user requirements in developing countries.

To some, the theme of the Seminar may sound appropriate, to others it may not . Obviously we associate plastics in our daily life with buckets, baskets, kitchenware and scores of other consumer items.

Lately the petroleum producing developing countries are in the process of industrialization and diversification and plastics is one such field being exploited. The need to integrate plastics industry with the production of building materials and components to meet the requirements of local building industry has been realized in view of the potentialities plastics offer for a variety of building applications. There have been several technological development gaps in this field among developing countries and adoption of plastics materials technology suiting the local country requirements is one such prime factor. It was in this context that today's Seminar was conceived at the Expert Group Meeting on the use of plastics in building industry convened by UNIDO, during 1971, and again recommended in the UNIDO Report as " Prospects for increasing utilization of plastics in the building industry in developing countries "(1974), prepared by the author.

During its deliberations in the course of next five days it is expected that the experts gathered here from developed and developing would arrive at a consencus and formulate objective recommendations for the development and introduction of need-based building applications in plastics keeping in view the local service requirements of building industry. Our focus is ' developing countries ' and our aim is to attempt to provide an opportunity to engineers, architects, builders and research scientists from these countries, for free and frank discussions, with a view to evaluating the past, analysing the present and recommending the future in the field of plastics building applications.

THE STRUGGLING PAST

Building is the oldest technology, and the building industry is craft-based. Its methods of operation, characteristics and price of traditional materials have in large measure dictated structural and architectural forms. Traditional materials are time-tested, thus more reliable in use. Building materials, as is well-known, constitute an important factor influencing the total building costs, which in turn are rising rapidly as against the consumer price indices, wages tend to rise more rapidly than the costs of building materials. In other words, housing is becoming more costly in relation to other goods and services.

In the search for new and economical building materials, major research and developmental efforts in advanced countries have been directed to plastics. By 2000, it appears, that Synthetic products (Thermoplastics, lacquer raw materials, adhesives, synthetic fibres etc.) will account for about 78% of world consumption of structural materials while metals will represent only 19%.

Going through the history of development of the use of plastics in the building industry since early fifties, one comes across interesting facts. One of these has been the excitement on the part of the plastics industry to coin terminology such as 'Building with Plastics' and Plastics as Building Materials. In the observations of engineers, architects, builders and building code officials, such a terminology had unfortunately not been kind enough to project the truths about performance of plastics under conditions of use. The reverse has also been true on the other hand, when the users in the building industry had at times not given thought to understanding the technical aspects of material properties of plastics and have invariably demanded of plastics, substitute physical and mechanical characteristics offered by conventional materials. Much more unfortunate and uncompromising facts relate to the efforts of the plastics industries and experts in industrially advanced countries by offering 100% plastics houses for solving housing problem in developing countries. To date, more than 250 plastics building systems have been designed in major plastics producing countries, none if any has been found to be economical as desired, either for the developed or developing countries, and these systems have remained as development efforts, or at times solutions to 'Emergency Housing'.

Plastics as new materials have advantages and limitations in terms of their applications as building materials. In the early days of development of these applications, there had been charges and counter charges by the building industry that the plastics industry had been working in isolation of the user requirements, designing components without any consideration to the fact that the material properties of plastics were much different from those of traditional materials. In the process of increasing tonnage both in production and sale, the plastics industry had at times over-advocated certain building applications, overlooking the local building industry requirements, and accusing the latter of conservatism. This had been the philosophy both in developed and developing countries. In developing countries, one had been impressed only by the successes achieved in advanced countries, overlooking the reservations, failures, and obvious resistance to the adoption of plastics in building. This attitude had led to misapplication and outright rejection of the philosophy of plastics in the building industry.

In this connection the following remarks of a Senior Architect of Greater London Council addressed to the plastics industry will be of interest :

> " It is our opinion that as vast and complex industry, you have not always done your 'home work', it is necessary for the industry to go to the grass roots, to do original research to ensure that plastics perform in their own right and not as a copy of the traditional materials they are replacing. Frequently plastics are better and cheaper than the existing traditional

products, and also require less maintenance. Produce new designs which suit the material and the purpose."

"Try and introduce some degree of co-ordination between the manufacturer, and not to have to write British Standards to suit what is on the market. Consult users before spending quite vast sums of money in tooling up for a product which may not be suitable for the market. And finally regard plastics in association with other materials that go into a building. Manufacturers in so many industries design their products in isolation with the best intentions only to find that they are incompatible with the other materials which form part of completed structure."

The bulk of traditional materials are produced with a minimum of conversion effort. The production of sophisticated materials like plastics had necessitated the importation of manufacture and applications technology for developing countries Plastics materials were successfully evaluated as alternatives to metals and timber in several building applications, but this required the establishment of indigenous plastics industry.

In industrially advanced countries, over 85% of total plastics production for the building industry is reported to represent use in floor, and wall coverings, foam, laminated sheets, building components, film and sheet, pipes and profiles and between 100 - 150 Kg. of different plastics materials go in for an average house built today. In fact a chemical company in the UK has estimated to have achieved a figure of about 760 Kg. of plastics for a typical three-bedroom house. The approach all along has been to enhance the standard of living in such houses by providing new designs and better performance of building components based on plastics.

Discussing the uses of plastics in architecture, Mills has made the following observations:

> "The early protagonists of plastics in building rendered the plastics industry, a considerable dis-service with their phantasy plug-in, clip-on or throw-away buildings and cities, miraculously exempt from the restricting influences of building legislation. It is unlikely that we shall ever be able to afford to treat buildings like mass produced motor cars, as short life, consumer goods which can be traded - in every two or three years for the latest model. Firstly, short buildings are notoriously expensive - experience in the exhibition world has proved this point with unfailing regularity and secondly, the owners or occupants of buildings tend to regard them as permanent. The plastics industry is still young, and must find its proper place in relation to the world of architecture and building. It is unlikely to be through integration where the now man-made materials play an ever increasing role in the technological development of the building industry. The architect is continually bombarded with technical literature and has to be concern himself with all types of building materials, old or new. In the field of plastics we need simpler information with less reliance on complicated chemical formulas, and more information on such things as the compatibility of one plastic to another or to other materials, and performance of the product in specific conditions over a reasonable period of time."

All-plastic buildings are curiously scarce in America despite their presence in Europe, and their popularity at World Fairs in New York, Seattle and Montreal. Yet nobody knows more whether plastic buildings could be sold in America, if only they were built. But one thing is certain. Builders are likely to leave such speculation to students of architecture and sociology for as long as they can get by with stereotypical buildings. Nor are they apt to be tempted by the dubious carrot of lower building costs either. True, plastic houses will be factory-built at reduced labour costs and they would use materials in the most efficient manner. But plastic is not yet a bargain material in the construction industry and it is likely to stay on the shelf until it is.

In Europe, great efforts were directed by the plastics industry towards infiltrating tradional building construction with plastics materials, while experimental structures got less financial support than ever. The prototypes of early sixties had not found a market and of the heavily promoted Futura Houses, only three were up in the Federal Republic of Germany.

Practically all the major chemical companies producing plastics materials in the world engaged themselves in development and evaluation of building applications in plastics. Plastics Development Houses were designed and put up and these helped to project the concept of potentialities plastics provided to the building industry. Technical literature and data - invariably commercially oriented were made available by the plastics producing companies to architects , engineers, and builders. The attempt was to bridge the communications gap between the manufacturers and the users. But this was one sided. The requirements of the building industry were rigid. So Building Research and Development institutions as also polymer research laboratories got active to undertake applications development and performance evaluation research. Notable examples in this direction have been the contributions of Building Research Station, Fire Research

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Station, RAPRA in UK; Division of Building Research of CSIRO in Australia, Division of Building Research of National Research Council of Canada, National Building Research Instt. of South Africa, CSTB of France, CSTC of Belgium. Trade and professional bodies/institutions and independent promotional development Committees/Groups, were equally active. These included Institute fur Bauen mit Kunststoffê , Darmstadt, Intercontinental Club for Plastics use in Building and Building Engineering, The British Plastics Federation, the Society of Plastics Industry (USA), the Plastics Pipe Institute (USA) Department of Architecture and Building MIT, University of Surrey Deptt. of Civil Engineering, Guildford. The major plastics producing companies engaged the services of professional architects and civil engineers to help them identify the field of building applications. International meetings and Seminars on the Subject were frequently convened for exchange of experience in the field. For the plastics industry the struggle was for existence and to exploit a major field of application, whereas for the engineers, architects, builders and research scientists it was an opportunity to probe into science and technology of a new group of materials. Voluminous literature has been documented in this field. And this has been a continuous process.

The USA, the world major producer of plastics continues to be faced with problems of consumption of plastics in building and construction. Plastics comprise about 5% of the building materials used in the USA but it has to reach 10% mark by 1980. And to achieve this target,

(a) building codes have to be standardized,
(b) resistance to the use of plastics by the building trade overcome,
(c) realistic flammability standards developed and adopted, and

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(d)flame retardent low-smoke materials developed. There appears to be an absence of proper communications channels between plastics building materials suppliers and those involved in decision making in the building industry, architects, engineers, designers, contractors and municipal planners. It is acknowledged that by and large these two industries are not on the same wave length, the gap remains, and its bridging remains, the prime challenge of the decade. While the industry is searching for ways of reaching the builder, it is moving ahead steadily in improving its products and raising its own standards.

The struggle of the plastics industry for existence and co-existence with the traditional building materials industry has been rewarding. That today plastics heve been identified as useful materials for upgrading the utilities and services in the building industry. The whole range of plastics materials have been studied and their building applications developed, experimented and are being perfected. These are listed out in Appendix I. The building elements wherein plastics have successfully been tried and are in use include, the sub-structure (damp-proof course etc.) primary elements (infil panels, partitions, floors etc.) secondary elements (window frames and stays, roof lights, door panels and furniture); finishes (internal wall decoration, wall cladding, floor coverings, skirtings, stair nosings); services (water supplies, soil and drainage systems, cisterns, taps, overflows etc.) ; installations (electrical conduct, wiring, switches, plugs, lighting fixtures); fixtures (curtain rails, working surfaces, sinks, toilet seats, etc.) building and site (fence rails, wire fencing etc.)

THE DEVELOPMENTAL PRESENT :

The building applications in plastics gradually got themselves identified in the building industry. Comparative consumption potential of plastics in building was appreciated by the building industry. Today over 25% of world production of plastics goes into various building applications. As an example the Graph illustrates the distribution of plastics in building applications, and Table demonstrates the consumption figures for 1974 and 1975 in the USA. Plastics have made notable contributions when employed as auxiliaries to other traditional materials. This way plastics have helped improve performance of traditional materials like wood, concrete, and steel. As auxiliaries plastics have been found useful in surface coatings, adhesives, and sealants, additives and impregnants.

The faults of materials known and utilized for hundreds of years are often overlooked and those of new materials are over-emphasized. Wood, concrete, and steel are useful materials, yet who has not seen a rotten board, cracked concrete, and badly corroded steel. This lack of perfection never means that no steel, wood, or concrete should be used. Conversely these facts brought out the necessity of intensifying combined efforts of the material manufacturers, the users and research workers to find practical solutions to this problem and plastics play an importent role therein.

Wood The oldest example of conventional material i.e. wood has undergone developments that enhance its natural properties help to overcome its limitations, and extend its usefulness. The use of urea and phenol-formaldehyde resins as adhesives in the manufacture of plywood and chipboard is universally accepted. Fabrication on highly sophisticated laminates using different

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grade of timber with resorcinol formaldehyde adhesives is a useful development. Roof structures, girders in ocean-going yachts and structural members are now fabricated in timber providing dimensions, strength, properties and designs.

Useful work has been carried out in the manufacture of wood-plastic composites by high-energy radiation induced polymerisation. The earliest work in this direction was reported from the USSR and this technology is now available in the USA Japan, Finland, India and several other countries. It has now been well established that medium soft wood, could be impregnated with commercial monomers such as methyl-methacrylate, styrene, and vinyl acetate, and polymerised by gamma-radiation in situ. Such a process imparts many of the useful properties in wood, e.g. dimensional stability, integral finish, and resistance to wear and damage is increased. Possible applications for such composites, if found economical would be for door, and window frames thus finding an outlet for cheap timber which has been until recently neglected by the building and construction industry.

Polymeric materials have brought about marked changes and improvements in protective and decorative surface coatings, paints varnishes, and lacquers. These are now based on alkyds, epoxy, polyester, silicone and urethane resins. Such finishes on wood retard the swelling and shrinkage caused by changes in moisture content that accompany fluctuations in the relative humidity of the surrounding air.

Lamination of vinyl film on plywood, particle board and hardboard, is yet another way of providing decorative and protective finish. Furniture, stereo, and kitchen cabinet makers are prospective customers for vinyl clad wood-based panels.

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<u>Steel</u> The high corrosivity of steel, has necessitated a much greater attention to be provided for protection by surface coatings, than is required for wood, or bricks or concrete. Corrosion protection has been an exclusive domain of paints, and lately it has been achieved with a great variety of plastics and application techniques, and at the same time fulfil a decorative purpose in a number of end uses of steel.

Polyethylene can be extruded on to steel pipes, or is applied as a powder and subsequently sintered to an impermeable coating. Powder coatings based on epoxy resins give the highest corrosion protection together with high-resistance to mechanical damage.

PVC can be applied as 'Plastisol' coating, or film lamination on to steel sheets, in different colours and given an embossed finish. Such PVC coated steel sheets can be fabricated into corrugated roofing sheets and cladding panels.

The performance of concrete can be improved with plastics in the following two ways:

(a) On the surface of an element or construction, with decorative and protective surface coatings, adhesives sealants, road pavings, foams, or moulds and shutterings.

(b) In the mass, by incorporation of polymers added in the forum of an emulsion, or as monomers which can polymerise in situ while concrete is setting, or in fibrous form.

Surface coatings on concrete for decorative or protective purposes are well established, and over the years have proven to give outstanding performance as coatings on concrete. Although fair faced concrete can be made reasonably good, it is too often seen to deteriorate after 5 to 10 years' by dirt collection or rust staining.

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The use of protective coating's is gradually penetrating in the concrete factory itself. Concrete sewer pipes can be ordered with a factory-lining of resinous materials like heavy duty epoxy compounds, epoxy/coaltar or polyester formulations.

Epoxy adhesives are yet another useful development which has become well accepted throughout the concrete industry. As the strength of the bond is as strong as the concrete itself, design stresses can be the same as in the case of monolithic concrete. The method of repairing concrete cracks by epoxy resin injection has been successfully applied to numerous structures of various types. The repair process not only eliminates the unsightly appearance but also restores integrity of the damaged concrete.

Caulking compounds and sealants based on elastic polysulphides, silicones, urethanes, epoxies and butyl rubbers are used on a large scale to solve the problem of joints between cladding panels on walls and many other elements. They can be applied by gun, as pliable strips or pre-formed profiles (gaskets). Then high elasticity enables these sealants to follow thermal movements of the concrete elements. They have no structural functions like the adhesives have, but serve generally to keep the weather out, and plastics sealants are generally replacing bituminous sealers.

Plastics foams can be combined with concrete for a number of end uses. Concrete when poured onto slabs of either, polystyrene or polyurethane foams, adheres satisfactorily after setting. This is one way of fabricating sandwiches, either in situ on the building site or in pre-cast concrete works, Another method is to pour the ingredients for polyurethane foam on or

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between hardened concrete faces and let the flam insulation layers form in situ. The foams in such sandwiches provide insulation against impact sound transmission in floating floors or heat insulation in a number of applications.

Glass-fibre reinforced plastics (GRP) based on polyester or epoxy resins are finding a wide use for re-usable moulds. The high cost of GRP moulds is off-set by savings resulting from their high durability and the great dimensional precision and fair finish of the moulded concrete elements. The moulds can also be electrically heated through built-in wiring to speed up the setting of the concrete so as to reduce the cycle time between pouring and demoulding.

Polypropylene moulds can be used on site as shuttering in the construction of coffered floors.

Expanded polystyrene is used as lost shuttering while the foam is left behind to improve the thermal insulation properties of a wall. Adhesion of concrete to boards of polystyrene foam is comparable to the cohesive strength of the foam itself which is an advantage where an insulation layer is required.

Thermosetting Concrete This is a designation given to a material consisting of fillers and binding agents.
The conventional portland cement is replaced by polyester resin in this type of concrete. The material has been developed by a German firm under the name ' Duraplast ' concrete, and in UK, the trade names given to the product are 'Estercrete', and ' Agresin'. The fillers tried and found suitable include quartz sand, gravel, silica, dust, stone dust, calcined fint, and pulverised fueld ash (flyash). Suggested applications for thermosetting concrete are, precast drainage channels, ..

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cladding and fascia panels, which it is claimed, can be one third as light or four times stronger and more resistant to chemical attack and weathering, low-water absorption, low-shrinkage and quick hardening, than conventional concrete. Other applications include for window frames, window sills, gullies for effulent water, drainage troughs, paving blocks, road posts, and fence posts. A machine to cast thermosetting concrete has been developed by a German firm, the machine has continuous output (between 10 and 400 Kg/mm) and quick mixing (o.7 mm).

Polypropylene chopped fibres (fibrillated fibres) of staple lengths ranging from 10-100 mm are added in proportions of 0.2 to 0.4% by weight of total concrete. They can be mixed with concrete or mortar in all types of conventional mixing equipment and the 'Caricrete' products made compare favourably with normal unreinforced concrete and have the following advantages:

(a) very much improved impact;
(b) the ability of the article to remain virtually in one piece after being cracked;
(c) a residual strength after cracking;
(d) improved flexural strength.

Thinner but structurally adequate concrete panels have been designed using polypropylene chopped fibres as reinforcement. Such panels offer savings in construction costs, less concrete per element, no prefabrication and positioning of the steel mesh in the unit also savings in transportation and erection costs.

Extensive work is reported on air-supported structures using plastic coated fabrics like nylong coated with PVC. Also instand parachute plastics houses for disaster areas have also been developed. The earliest examples of air supported structures installed in Europe 15 years ago are still going strong, on the other hand ways of using fabric roofing are becoming

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more sophisticated. Between 50 and 100 projects in a widening range of end uses were completed during 1974 in West Germany. A typical o.7mm-thick membrane involves 400 to 500 gm/Sq Cm. of PVC plastisol. Earlier air-supported structures were limited to industrial warehousing and winter tennis, but new applications include roofing for service stations, playgrounds, building entrances, swimming pools, sewage treatment plants, and shopping areas.

Glass fibre reinforced polyester resin is yet another material which has been widely expolited by designers for putting large structures both in Exhibitions and Fairs, and in renovation of old historical buildings.

Plastics piping systems for water supplies, drainage, soil and waste systems, electrical conduits, in materials like PVC, PE, ABS, Polypropylene have made a very useful progress in the development of plastics in building, and these have come to stay as economical building applications.

Wall coverings, claddings panelling and partitioning in a variety of plastics materials and profils have been developed and are in the building trade market.

Plastics have infact made a real impact as components and services in building applications, and these include building hardware. Sanitary fittings and fixtures, electrical fittings and fixtures, floor and wall coverings etc. These are now accepted products as against the conventional materials.

The developing countries have been following the trend of developments of plastics building applications. The objective evaluation of these applications suiting the local requirements of the building industry has been the major factor of consideration for developing countries. Infact plastics industry exists practically in all developing countries, and where

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production of plastics raw materials is not established, the local processing industry depends upon imports from countries like USA, UK, Japn, West Germany etc. Polyethylene, PVC, polystyrene,,polypropylene, phenolics, ureas, polyesters continue to be the major plastics materials converted into a range of building products. The developing countries are generally faced with ' economics ' of the use of new materials and their acceptance by the local building industry, performance and innovations come next. The emphasis all along for developing countries should be to develop and introduce need-based building applications in plastics, not overlooking the fact for promoting low-cost or basic-housing for the growing population. The development of socially and economically acceptable 'shelter' for slum dwellers, using plastics preferably in continuation with traditional materials is yet another important aspect of study.

Plastics materials perform on their own merits. The increasingly severe demands imposed by our buildings dictate the performance concept of adoption of new building materials including those based on plastics.

In this connection, the following observations of Prof Ir. M. Gout of Delft Technical University, while summarizing the ideas of 23 experts at the close of the Congress on the use of plastics in the building industry (Rotterdam, April, 1970), would be of interest.

> "The know-how of the building world in the field of plastics is very small, while on the other hand, know-how of the plastics world in the field of building is not much large. The preparedness of each side to cooperate with the other is present, but there is suspicion on both sides based on failures, which are characteristics of every new endeavour. This method of looking at things is now fairly generally accepted,

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and becomes especially interesting for the the use of plastics materials in building. In the built-in-fixtures, plastics materials have already taken a place from which they cannot be removed, although it can be accepted that before 1985, plastics materials will not play any role of importance in the bearing constructions."

"In the past the mistake has often been made of thinking that the production methods for automobiles can be easily used for the building of houses. This may possibly be the case in the very distant future. But in the next 30 years we shall certainly be living only in the transitional stage in which the real industrialization of living accommodations and of building in general will make a very slow entrance. Especially in building. Will the future use of plastics materials be to an important extent in their combination with other materials, and also to improve qualities of the traditional materials."

Prof Albert G H Dietz has the following observations on the development of building materials technology:

"Many building materials are strangers to the architects who use them. Education in materials in the usual architectural, engineering and construction curricula cannot be said to be outstanding, particularly as preparation for innovative uses of materials possible today. Much such curricula do not require even such elementary science as chemistry, without which a real undertaking of materials is impossible. The result too often is a confused picture of materials and excessive reliance on manufacturers' literature, which tends to reflect current practice rather than innovative applications. Furthermore, the building fraternity is notoriously absent from the development of the very standards that largely govern its uses of materials."

"Materials cannot be considered alone divorced from their position as an integral part of the building process, the use of the buildings, and their place in the community. The success of a building is largely dictated by the ability of its materials to meet the building objectives."

"Among the important factors that influence the use and development of materials are, scarcity and shortage of materials and skilled labour, advances and changes in materials technology, industrialization of the building process, the growing awareness of the importance of life-cycle, costing of buildings, the increasing importance of energy, the growth of performance concept in design and legal controls, and interactions among these influences."

THE FUTURE INSISTS ON PERFORMANCE WITH CONFIDENCE

Buildings are expected to last a long time, so is the case for a building component. Durability and maintainability are important properties for a building material. Plastics is a science-based industry supported by research and development incorporating scientific methods and research results throughout its structure. It has pioneered quality control and testing of its products. The quality control in building is traditionally exercised by the designer-architect, engineer, usually in the on-site, factory. Plastics are basically 'delicate' materials when compared with traditional building materials.

Today, there is a shift to the consumer. Ways are being found to express the requirements of the user of buildings and to incorporate them into specifications for building components which define the performance required. Performance specifications both of material and the design of the component are a necessary part of a programme of

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change to interchangeable building components.

Durability of materials or components is one of the most difficult to measure even in the laboratory. Durability, and indeed most other requirements, of manufactured products begins with the product in use. But who is the user of a building component ? Particular user requirements decisions could influence usage of materials. For instance, should a rigid PVC pipe support a ladder placed against it or a bucket full of water hung against it ? Manufacturers of these pipes could be seriously embarrassed, if the decision was ' yes '.

For most users, durability is a matter of abrasion, wear and impact resistance. Where component has to be manipulated, such as taps, catches, hinges, handles, ergonomic considerations are also important. Maintenance of aesthetic appearance must also be considered.

Appendix III illustrates the expected life of some of the common building components

Composite materials technology The demand for weather resistant, flame retardant and smoke suppressant plastics materials for their use in building applications has set forth useful development work in plastics composite materials - using a variety of fillers, industrial and agricultural wastes. Some of the promising improvements are expected from the following:

(a)Wood-floor PVC resin composits for extruding door, and window frame profils.

(b)Calcium silicate fibres increase chemical resistance of polypropylene.

(c)Treated asbestos, silicas and clays upgrade performance in many types of resin.

(d)Mica, talc, glass, heads, and glass spheres do an upgrading job on dimensional stability.

(c)Alumina Trihydrate scores as a flame retardant, filler and smoke suppressant, and as such as 60% loading in resin has been achieved.

Many materials used throughout the ages in building construction have been the types to minimize the failures and there are those that fail. Product reliability, low maintenance and comparative durability are the major factors building industry looks for while considering the use of new materials including plastics. The increasingly severe demands imposed by our buildings often cannot be met by simple single-component materials and call for the combined behaviour of several materials, new and traditional in composite form to provide properties not attainable by the individual constituent material. In other words, composite materials are among the most promising of all the recent development and the contributions of plastics therein have scope for study and experimentation. Such developments incidentally prompted by the current "Caution" advocated by the building industry in advanced countries due to the fact that plastics offer fire hazards and produce toxic fumes.

Various combinations of plastics in different forms with conventional materials have been studied, and some are under experimentation. These include the following composites:

(a)Glass-fibre reinforced polyester resin (GRP)
(b)Sandwich panels using plastics foams as core materials, and different skins of plywood, asbestos cement, aluminium and steel sheets and GRP laminates;
(c)expanded-polystyrene filled lightweight concrete;
(d)thermosetting concret., using polyester resin and various fillers such as gravel,,quartz-sand and silica dust;

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(e)PVC coated, or PVC surfaced steel/aluminium sheets for roofing and siding panels;

(f)combination of marble chips or of similar aggregates in various colours with thermoplastic synthetic resins;

(g)cellulose reinforced, or wood flour (saw-dust) filled PVC for extruding profiles suitable for door and window frames, and similar applications;

(h)wood-plastic composites, and -

(i)stone-dust, or flyash composites with polyester resin;

(j)waste-paper and polyethylene composite.

Applications development and materials technology

Applications development is time consuming and costly, and building applications in plastics are no exception. Before the plastics materials can move into the construction field in developing countries, areas where their desirable properties will be found useful must be determinded and their subsequent use in specific products under local conditions must be developed in acceptable forms. Such products must be evaluated and compared with the conventional materials in general use. With limited resources for research and development work in plastics in developing countries, their adoption for the building industry has called for organized development and careful evaluation.

Research and development are fundamental for successful introduction of new products and techniques in the building industry. The local plastics raw materials manufacturers cannot escape the responsibility of involving themselves in contributing their share in money and material in this direction by undertaking developmental research in co-operation with the local building industry. Though this work demands balanced resources, the future progress depends on the successful role played by these two aspects. The indigenous research has relevance to the needs of the local building industry and the borrowed or imported research could only be useful as a reference.

With the continuous pace of development in plastics materials technology in advanced countries and the diversification of applications in the building industry, the developing countries need consider evaluating plastics from time to time to determine their suitability for adoption in the building industry. Materials technology of structural plastics foams such as that of PVC, Polystyrene and polyurethane, have lately been reported to offer useful building applications such as door and window frames as direct substitutes for timber and steel. Though the most accepted plastics materials like PE, PVC, polystyrene, polypropylene, phenolics, ureas and polyesters continue to dominate the building industry, the acceptance of their applications technology for a particular developing region requires careful assessment.

The development of composite materials using locally available traditional materials, industrial and agricultural wastes with plastics for locally acceptable building applications hardly needs any emphasis.

The overall ap roach to this aspect of the study could preferably be country-wise and if there are common factors such as that of socio-economic and climatic conditions among a few countries in a particular region, it could be region-wise. The results of research could be communicated mutually and experimented. In other words, regional research studies could be more useful among developing countries in this direction.

The building systems using plastics building components

The commercial approach to houses to be all-plastics when talking in terms of low-cost housing needs to be carefully evaluated in the light of economical and environmental aspects, local building and fire regulations and in respect of user acceptance of plastics by the local building industry. A number of all-plastics and semi-plastics houses have been designed and erected in several parts of the world, and it would be desirable to evaluate their performance and collect and compile their case-histories under various climatic conditions. Such information is lacking, or else this could give clear indication whether all-plastic houses, Yes or No, in terms of low-cost housing. In the absence of sufficient evidence of user-acceptance of plastics-houses and their favourable economics for the benefit of developing countries to solve the problem of basic-housing, it is no use advocating the philosophy of such houses.

A frequently heard statement is that in the next quarter of a century we must build more structures than have been built so far, and that plastics could provide an acceptable solution. This is only commercially oriented philosophy. It may make more sense to upgrade the existing structures than demolish and rebuild. Plastics do have a large place in this field, but their use must fit the needs that exist.

It would be apparent from these observations that selective and judicious use of plastics in building should be found more suitable, useful and economical in the light of prevailing conditions in developing countries. In other words only need-based applications in plastics and their component-wise studies would make a visible impact towards universal approach for basic-housing. This is but one line of approach which is further to be supported by activities like the establishment of plastics industries in developing regions and its diversification into products of use in the building industry, education and training of users (builders, architects and engineers), quality control and performance specifications, study and development of applications meeting the local building industry requirements. This is a continuous process at least for the next ten years, and at international level. This needs to be co-ordinated by organisations UNIDO through the cooperation and participation of plastics industries in advanced countries. It is accordingly suggested that under the prevailing conditions in any developing country, the following building applications in plastics should be considered for adoption in order of preference :

i) Piping systems in rigid BVC
for cold water services, soil and rainwater, and underground drainage systems, electrical conduit,etc.

ii) Sanitary fittings

such as taps, sink and basin wastes, weste traps float ball and valve, syphon for flushing cisterns in PE, PP, ABS and acetal resin.

iii) Overhead water storage tanks in PE and GRP

flushing cisterns in HI PS and PP

iv) Building hardware

Such as door handles, latches, window stays, hinges, etc.,,in PF UF, PP, Nylong and acetal resin.

v) Door and window frames, and shutters

in wood-flour, PVC composite, structural PS, PVC foams, and wood-plastic composites.

vi) Cladding and roofing panels suitably designed

in composites consisting of industrial wastes like flyash, stone-dust with polyester resin (thermosetting concrete), PP-reinforced concrete, PE waste paper conversion into corrugated boards for temporary roofing sheets, and sandwich panels

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Building systems based on the combination of components (i)to (vi) above, could be the nearest approach to the basic-housing concept - traditional building materials would of course be the basic materials of construction in such systems, so is the case with the design and shape of the dwelling unit.

The above applications would facilitate substitution of costly and scarce conventional materials like cement, steel, timber and non-ferrous metals in some of the most common and essential building components for a dwelling unit of any economic size. These would require study of the locally available raw material resources, production and processing facilities and their integration with the building materials industry through existing or proposed petrochemicals-based facilities for plastics production.

Performance requirements and evaluation

Since plastics are relatively new building materials, there are still reservations in developing countries on the part of architects, engineers and builders in adopting or specifying plastics for particular building applications, especially in the absence of sufficient quality control and standardization both in the manufacture and use. The same has been in existence in industrialized countries also. The technical information provided on performance of plastics building products by plastics manufacturers has invariably been questionaly accepted by the building industry, and at times misleading. Standard specifications for new building products, including plastics, do help in furtherig an appreciation of the technicalities of the material application, provided these are sufficiently supported by local experience in manufacture and usage, and not merely based on the experience of other advanced countries. The current approach is to have performance specifications of new products through technical assessment and evaluation of their characteristics under actual condition of use. The performance-in-use concept of technical assessment of new building products and technique, including plastics, first introduced in France, under the 'Agrément System' and later in the United Kingdom, and other countries in Europe, has proved to be very useful for the building industry to adopt innovations in materials and construction techniques. Such a practice has helped in making plastics acceptable for a number of building applications. The Agrement certificate of approval, as it is issued by the authorities under the name of independent bodies,, 'Agrement Boards', is issued for the new product technically assessed for its suitability in the building industry under the 'Agrement System'. It is reported that more than 50 per cent of building systems tested and approved by Agrement Boards in Europe are plastics. Such a proposal of introducing the 'Agrement System' appears to be promising, since an awareness of adopting new materials and techniques including plastics is gradually evolving in developing countries in relation to the size and growth of construction activities. The need to constitute independent bodies like 'agrement Boards' country-wise or region-wise is called for. For instance, in the ECAFE region 'Asian Regional Agrement Boards' under the designation 'Asian Agrement System' could be constituted collectively through the initiative of and testing facilities available in Japan, Australia, India, Indonesia and the Republic of Korea. Such a course of action would facilitate the growth and judicious adoption of plastics and other new materials by the building industry.

The Centre for Building Technology at the National Bureau of Standards has evaluated the structural adequacy of building systems promoted by HUD. Two of their reports have dealt with systems involving plastics. The NBSIR 73-188 (99 pp) entitled 'Structural tests on housing components of glass-fibre reinforced polyester laminate' (NTIS document PB-221 183); and NBSIR 73-105 (47 Pages) is entitled 'Environmental evaluation of polyurethane foam-core sandwich panel construction' (NTIS document Com-73-10858). These investigations are likely to provide the background information needed to determine the conformance of these building systems to the national building codes.

In an informative study carried out at the Building Research Establishment (BRE CP 11/75) it has been concluded that surface appearance of unplasticised PVC rainwater goods changes on weathering over long periods. Painting is likely to be called for to maintain their appearance although it is not necessary to protect them from other deterioration. Paint adheres rather better to PVC surfaces after weathering than when they are new and unweathered. It might, therefore be more effective to delay painting until the surfaces have weathered. It might, therefore, be more effective to delay painting until the surfaces have weathered. Difference between extruded, injection moulded and other surfaces are not so great as to show up significant differences in retention of paint films on weathering. The study could further necessitate carrying out investigations to ascertain the suitability of colours shades of unplasticised PVC pipes and fittings and recommend the most suitable colours for these pipes under conditions of use in tropical climatic conditions.

In The BRE (UK) CP91/74, entitled 'Polymeric Materials in Fire' makes a review of the major uses of polymeric materials in buildings and their behaviour in fires. It concludes this review with the comment that the research in progress on the problems of polymeric materials in fires should in due course lead to information which can be used as a basis for the control of buildings. It further goes to say that the major outstanding question to be answered is whether in comparison with the use of traditional materials in buildings, the current or potential future use of polymeric materials presents as increase in fire hazard or a change in its nature, and in particular, whether:

i) The presence of plastics in fire significantly impedes the evacuation of a building on account of :

a) an increase in the rate of growth or spread of fire

b) an increase in smoke and toxic products

c) the presence of other hazardous characteristics specific to plastics

ii) the use of plastics for furniture and upholstery requires higher standards of fire safety in buildings,

iii) existing testing techniques are adequate for polymeric materials.

Efforts are continuing to collect information on these matters, to facilitate the authorities in various countries and the Building Regulations officials, to take the most desired course of action in the light of the responsibilities they have to undertake.

Regional experience and collaboration

A number of developing countries including India, Iran, the Republic of Korea, have built up expertise in the manufacture and use of plastics building products. There is good scope for exchange of experience among these countries and theirextension to less developed countries. This could take the form of exchange of technical know-how, the export of plastics building components, the formation of regional working groups, the organisation of regional seminars and meetings and publication of technical reports and notes on recent developments.

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The major plastics manufacturing countries could play an important role in transferring through the developing countries an application-development technology, and in assisting those countries in developing regional collaboration among themselves.

Developing countries can ill-afford to invest large sums of money in research and development activities in the use of plastics in building. Certain aspects of the problem are required to be studied locally, and for this purpose, regional experience and requirements could be pooled and work initiated through the research and development facilities existing in countries like Japan, Australia, India, Indonesia, the Republic of Korea, and Iraq. The plastics industry would do well in promoting regional collaboration by studying the local needs of developing countries, by participating and contributing in systematic research and development work, and by co-operation with the local building industry. UNIDO could assist such regional collaboration among developing regions.

C O N C L U S I O N

Adoption and Diversification through co-ordinated Approach

Since the latter half of 1973, the scope for expansion and diversification of plastics industry, has been questioned at various national and international meetings, in view of the dramatic increases in the price of crude oil. It is a known fact that hardly 3% of the crude refined in the world, is used for petrochemicals. There has also been world-wide inflation.

As a result the pattern of consumption of plastics has been seriously affected. This obviously called for re-assessment of the concept of dependence of plastics industry on petro-chemicals, and the competitive position of plastics in relation to other industrial raw materials in several countries. However, it has been observed through studies carried out both in developed and developing countries, that there has been substantial corresponding increase in the prices of traditional industrial raw materials, and in general, it is found that the increases for finished plastics products are in most cases of the same order as those of the competitive finished plastics products are in most cases of the same order as those of the competitive finished products made from other materials. It must also be borne in mind that although plastics compete with traditional materials on price basis, their technical performance also has relevance in their overall acceptability. Because of the density of plastics in relation to other raw materials, together with the less labour-intensive processing necessary for the production of finished components, plastics have remained competitive, despite the fact that overall increase in their raw material cost has been greater than that for other materials.

By 1980, it would appear that countries in almost all the developing regions in the world could claim to have their indigenous plastics industries. There will be good prospects for promoting the increased utilization of plastics in the building industry, though cost, applications development and [illegible] performance would continue to be major challenges that are expected to be faced by the developing countries. To overcome these challenges in the light of local demand on housing, is a continuous process.

The promotion of increased utilization of plastics in building in developing regions needs to be systematically organized and co-ordinated. This is possible through the joint cooperation and participation of local plastics and building industries, with the active collaboration of Building Research & Development Organisations. A selective approach of building applications in plastics would require to be analyzed in the light of user requirements and locally available potential raw materials resources. This is to be further supported by creating an awareness among local building industry, as to the advantages and limitations of plastics in building under local conditions of use. This could be achieved through organising education and training programmes for users at various levels, as get-togethers, meetings, seminars, publications of non-commercially oriented technical literature on various aspects of plastics in building. All these activities are required to be coordinated by a centralized agency in a developing country such as building research and development organisations and an Association of architects/engineers/builders, if existing, would be best suited for such a programme.

Since plastics are materials of recent origin for the building industry, the need to introduce these in the curricula of courses of architects and engineers at undergraduate and postgraduate levels, would also facilitate a better understanding of plastics as building materials for the future designers and builders of houses.

To facilitate and assess the increased use of plastics in building, it would be useful to establish 'experimental demonstration housing projects' incorporating plastics building components. This type of procedure will help evaluate service performance and user acceptance of plastics products under local conditions of use. This could further be extended to formulate 'Agrement System' for technical assessment and evaluation of new building materials and techniques in developing countries, along the lines carried out in the UK, France and other countries in Europe. There is hardly any need to have specific building system designs for plastics, and conventional designed houses with selective use of plastics would justify the promotion of plastics, and conventionaldesigned houses with selective use of plastics would justify the promotion of plastics in building. The local architects, engineers, and builders will appreciate the material properties of plastics better through such experimental housing projects, providing local experience.

These demonstration housing projects could be initiated in developing regions/countries and results of performance communicated regionally from time to time.

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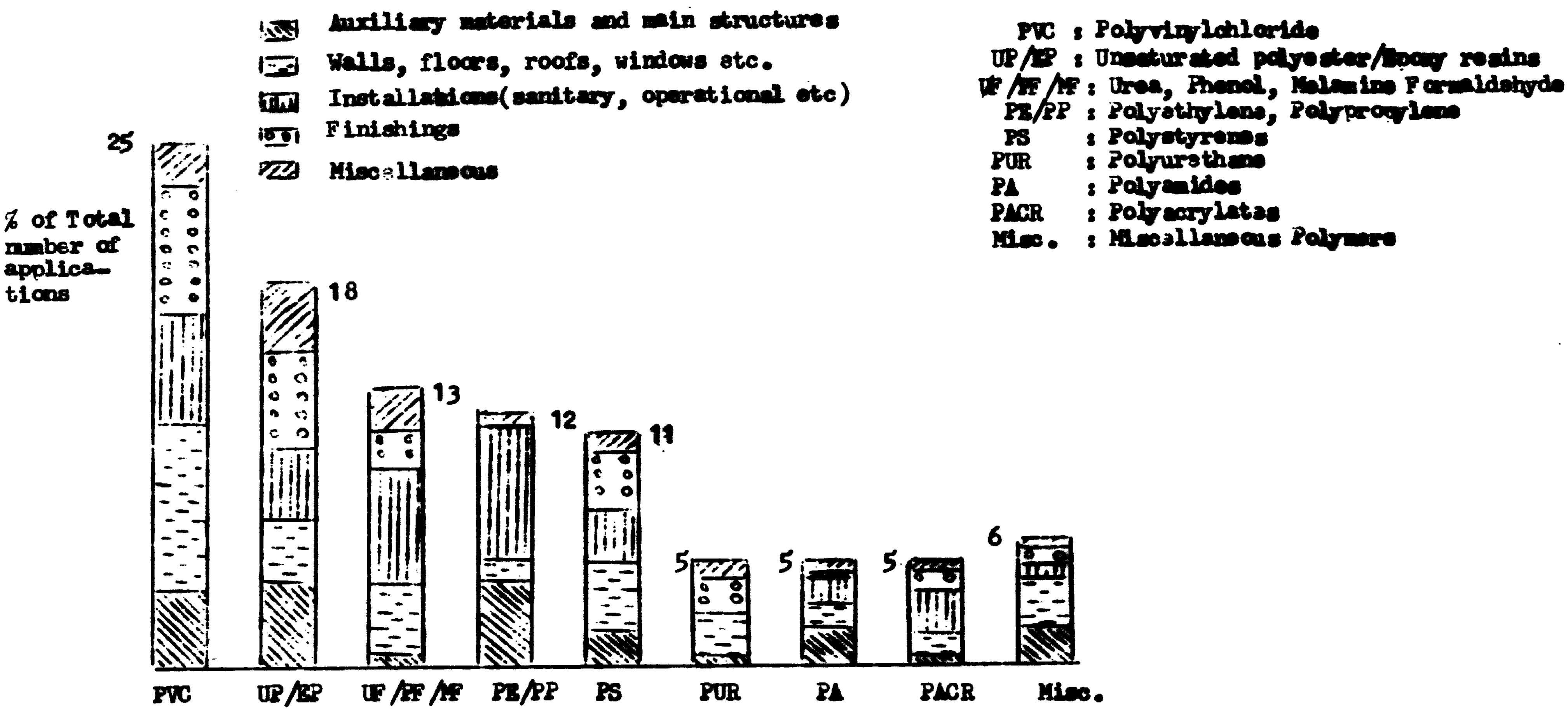
DISTRIBUTION OF TYPES OF PLASTICS IN BUILDING APPLICATIONS



(SOURCE:EKH Walkan, BOUW 23(1968)2036.

TABLE 1

CONSUMPTION OF PLASTICS IN BUILDING AND CONSTRUCTION IN THE US

Application/material	1974	1975
	1,000 metric tons	
Decorative laminates		
Phenolic	23.0	15.0
Urea and melamine	19.0	13.7
Flooring[a]		
Epoxy (includes paving)	4.6	3.1
PVC	156.0	131.0
Urethane foam (rug underlay)	15.0	14.0
Glazing and skylights		
Acrylic	42.0	39.0
Reinforced polyester[b]	7.5	6.9
Polycarbonate	14.5	14.0
Insulation		
Phenolic (binder)	105.5	74.5
Polystyrene foam	22.3	22.7
Urethane foam(rigid)	70.0	80.0
Lighting fixtures		
Acrylic	28.2	20.3
Cellulosics	2.5	1.9
Polycarbonate	2.6	1.9
Polystyrene	16.0	11.0
PVC	6.0	6.0
Panels and siding		
Acrylic	5.8	4.9
Butyrate	1.6	1.2
Polystyrene	5.0	5.0
PVC	44.0	40.0
Reinforced polyester[b]	47.7	40.5
Pipe, fittings, and conduit		
ABS	107.0	91.0
Epoxy (Coatings)	2.7	1.8
HDPE	150.0	110.0
LDPE	15.0	12.0

contd...

TABLE (Contd...)

Application/material	1974	1975
	1,000 metric tons	
Polypropylene	10.0	5.0
Polystyrene	41.0	36.0
PVC	557.0	452.0
Reinforced polyester[b] (incl. ducts and tanks)	51.5	51.0
Profile extrusions (incl. windows, rainwater systems, etc.)		
PVC(incl. foam)	75.0	65.0
Polyethylene	3.8	2.2
Plumbing and bath fixtures		
Acrylic	25.0	21.0
Polyacetal	3.8	3.3
Polyester, thermoplastic	0.7	0.6
Polystyrene	2.0	1.0
RP[b] (tub/shower stalls)	23.0	15.0
Resin-bonded woods		
Phenolic	112.0	94.0
Urea and melamine	256.0	171.6
Vapor barriers		
Polyethylene	98.0	70.0
PVC(incl. swimming pool liners)	29.0	23.0
Wall coverings and wood surfacing(inferior)		
Polystyrene	2.0	2.0
PVC	58.0	45.0
Total	2,257.3	1,817.1

a: Does not include bonding or adhesive grade materials

b: Includes reinforcements.

Source: Mod. Plast Jan.,1976
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APPENDIX I

USE OF POLYMERIC MATERIALS IN BUILDINGS

Key to polymer abbreviations

PE	-	polyethylene (polythene)
PP	-	polypropylene
UPVC	-	unplasticised polyvinyl chloride
ABS	-	acrylonitrile-butadiene-styrene copolymer
PS	-	polystyrene
EPS	-	expanded polystyrene
GRP	-	glass-fibre reinforced polyester
PMMA	-	polymethyl methacrylate
PTFE	-	polytetrafluoroethylene
PPO	-	polyphenylene oxide
CPVC	-	post-chlorinated polyvinyl chloride
PU	-	polyurethane
UF	-	urea-formaldehyde
PF	-	phenol-formaldehyde
MF	-	melamine formaldehyde
PVA	-	polyvinyl acetate
PC	-	polycarbonate
PVC	-	polyvinyl chloride

contd....2/-

I AREA OF APPLICATION

A Building

i.	WATER SUPPLY (cold water)	Pipes and pipe-joints (Mains and distribution)	PE,UPVC, ABS
		Cold water cisterns	PE,PP,GRP
		Cistern floats	PE,PS,PP
		Overflow tanks	PP
		WC cisterns	PP,PS
		WC seats	PF,UF
		Taps	PMMA,acetal, nylon
		Baths, basins, sinks	PMMA,GRP
		Jointing tape	PTFE
	(hot water)	Pipes and fittings	PPO,CPVC
ii.	DRAINAGE	Rainwater gutters, pipes and fittings, roof outlets	UPVC,GRP
		Internal sink and bath waste pipes, joints, traps	PP,ABS, CPVC,PE
		WC connectors	Plasticised PVC, synthetic rubber
		Soil and waste stack pipes, pipe fittings, cowls	UPVC
		Fittings for pitch-fibre pipes	PP
		Underground drain pipes and connectors	UPVC
		Inspection chambers, access systems	UPVC,ABS
		Pipe liners, pipe fairlings	GRP
		Cesspits, collection tanks	GRP

Contd...3/-

APPENDIX I

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PF	-	phenol-formaldehyde
MF	-	melamine formaldehyde
PVA	-	polyvinyl acetate
PC	-	polycarbonate
PVC	-	polyvinyl chloride

contd....2/-

iii	VENTILATION	Vent pipes and connectors	UPVC,ABS
		Ducting	UPVC
		Grilles	ABS
iv	ELECTRICAL	Conduit and trunking	UPVC
		Cable covering and insulating materials	Plasticised PVC, PE, natural- and synthetic rubber
		Plugs, outlets, switches, roses,etc.	PF,UF
		Light fittings, lampshades	PS,PMMA,PC
v	WATER- AND WIND-PROOFING	Damp-proof courses and membranes	PE,pitch/PVC, synthetic rubbers
		Water stops	Plastici-sed PVC
		Sarking	Plastici-sed PVC
		Draught excluder strips	Flexible PU
		Site protection, temporary glazing	PE
vi	THERMAL INSULATION	Many unlisted applications	Cellular plastics PS(EPS), PVC,PF,PU
		Flat roof insulation	EPS,PU
		Under-floor insulation	EPS

contd...4/-

		Wall cavity filling	UF, (PU, EPS)
		Pipe insulation	Flexible PU, EPS
		Ceiling boards	Rigid PU
vii.	ACOUSTIC APPLICATIONS	Impact sound absorption	EPS, PU
		Acoustic absorption	Flexible PU
		Anti-vibration mountings	Synthetic and natural rubber
viii	FLOORING	Tiles and sheeting	PVC, lino-leum, coumarone-indene, synthetic and natural rubbers
		Textile flooring and carpeting	Various synthetic fibres (PP, acrylic, nylon, rayon etc)
		Carpet underlays	Flexible PU, plasticised PVC, syn-thetic and natural rubber
		Industrial flooring	Polyester, epoxy, PU, rubber latex
		Binders for chemical resistant flooring	Furane resin, epoxy, PU
		Skirting	UPVC, plas-ticised PVC
		Stair nosing	PVC, rubber

Contd....5/-

ix	INTERNAL LININGS	Wall covering tiles, sheeting, wallpaper	Plasticised PVC, PS
		Coatings on boards	Plasticised PVC
		Decorative laminates, wall linings, counter tops	MF, PF
		Ceiling tiles, covings	EPS
		Suspended ceilings	PS, plasticised PVC
		Extruded sections	UPVC
		Mantelpieces	GRP
		Paint	Alkyd, PU, PVA, acrylic
		Decorative and translucent panelling, murals	GRP
		Stair hand rails	Plasticised PVC
x	DAYLIGHTING AND ROOFING	Translucent corrugated sheeting	GRP, UPVC, PMMA
		Roof and dome lights	PMMA, GRP, UPVC
		Roof cladding sheets	PVC, PF
		Corrugation closures Flexible roof membranes	EPS, flexible PU Flexible PVC, synthetic rubbers, pitch-PVC

Contd...6/-

		Window frames	GRP, UPVC
		Window glazing	PC, UPVC, PMMA
		Window furniture	Nylon, acetal
		Shutters, venetian blinds	UPVC
		Canopies, roller blinds	Plasticised PVC/nylon
xi	DOORS	Door sets, frame sections	UPVC
		Door furniture, hinges	Nylon, PF, PMMA
		Sliding door runners	Nylon
		Folding doors	Plasticised PVC
		Panelled doors	PVC, GRP
xii.	EXTERNAL WALLS	Weatherboarding	UPVC, PVF (on Plywood, aluminium)
		Composite Panels	GRP, PF
		Wall-ties	PP
		Fascias(Shops etc)	PF-MF, acrylic, GRP
		Architectural features(Cornices etc)	GRP
xiii	SUB-STRUCTURES	Bathrooms, heart units	MF-PF, GRP
		Church Spires etc	GRP

Contd....7/-

xiv	SMALL BUILDINGS	Disaster and holiday housing	Rigid PU, GRP, UPVC etc
		Air-supported buildings	Flexible - PVC, synthetic rubbers (neoprene, etc)nylon, polyester fibre
xv	MAIN STRUCTURES	Sports halls, domed roofs, swimming pool halls, warehouses, market buildings, structural roofs(dolded plate, etc), exhibition buildings	GRP
xvi	JOINTING MATERIALS	Gaskets	Synthetic rubbers (neoprene butyl etc), PE
		Mastics	Synthetic rubbers (thiokol, acrylic, silicone) etc
xvii	COMPONENTS OF COMPOSITE MATERIALS	Lightweight aggregates	PS
		Resin binders for concrete	Polyester, furan, etc, resins
		Additives for concretes, mortars	PVA, acrylic, etc
		Adhesives and binders for chipboard, plywood etc	UF, PF

Contd....8/-

B Furniture

i	Chair shells	PP, EPS, PE, GRP, rigid PU
ii	Storage units, shelves, drawers, cabinets, picture frames	PVC, PS, ABS, PMMA - (structural foams)
iii	Surfacing materials, laminates	Flexible PVC, MF
iv	Flexible foam (upholstery etc)	PU, natural and synthetic rubbers
v	Hardware, fittings	Acetal, nylon
vi	Upholstery fabrics	Flexible PVC Flexible PU
vii	Binders and adhesives (chipboard, plywood etc)	UF
viii	Curtain rails and furniture	Nylon, PVC

II PRINCIPAL AREAS OF APPLICATION OF MAJOR PLASTICS MATERIALS IN BUILDINGS

Polyethylene (polythene) (PE)	Cold water pipes, pipe joints Cold water cisterns Sink and bath wastes Cable insulation Damp proof courses and membranes Site protection

Contd....9/-

Polypropylene(PP)	-	Cold water and WC cisterns, overflow tanks Sink and bath wastes Fittings for pitch-fibre pipes Wall ties
Unplasticised PVC (UPVC)	-	Cold water supply pipes and fittings Rainwater gutters, pipes, fittings Soil and waste stack pipes etc Underground drain pipes, connectors, inspection chambers Vent pipes, connectors, vent ducting Electrical conduit and trunking Wall-skirting Roof lighting & cladding sheets, dome lights Wall lighting Window frames, shutters Door sets, frame sections Weatherboarding
Plasticised PVC	-	WC connectors Electric cable covering and insulation Water-stops, roof-sarking Floor coverings Wall covering tiles, wallpaper Coatings on boards Suspended ceilings Panel jointing strip Stair hand rails Flexible roof membranes Window canopies Air-supported buildings
Flexible pitch/ PVC	-	Damp-proof courses Roof membranes
Post-chlorinated PVC(CPVC)	-	Hot water and central heating pipes Internal sink wastes

Contd....10/-

Acrylonitrile-butadiene styrene(ABS)	-	Water supply pipes and fittings Internal sink and bath wastes Inspection chambers, access systems Ventilator pipes and grilles
Polystyrene(PS)	-	WC cisterns Wall tiles Light fittings
Expanded polystyrene(EPS)	-	Various thermal insulating applications - walls, floors, flat roofs, pipes, soffits Impact sound absorbing sheets Ceiling tiles
Polymethyl methacrylate(PMMA)	-	Baths, basins, sinks Tap heads Light fittings Roof and dome lights Wall and window glazing Door furniture Wall lighting panels
Polyurethane(PU)	-	Various thermal insulating applications Flat roofs, ceilings, pipes Sound absorption Industrial flooring, floor finishes Jointing gaskets Draught excluders
Polycarbonate(PC)	-	Light fittings Vandal-resistant glazing
Nylon	-	Tap fittings Hinges, door and window furniture Door runners Protective coatings

Contd....11/-

Phenol-formaldehyde(PF)	-	Decorative laminates(backing) and wall-coverings Electrical fittings WC seats Composite panels of foam as thermal insulation
Melamine formaldehyde(MF)	-	Decorative laminates (facing)
Urea-formaldehyde (UF)	-	Wall cavity filling(foam) Electrical fittings Adhesives and binders for plywood, chipboard, etc
Glass-reinforced polyester(GRP)	-	Cold water cisterns Baths, basins Pipe liners; pipe fairings Cesspits, collections tanks Roof lighting sheets, domes etc Wall panelling, decorative, murals External cladding panels Fascias Bathroom, heart units Structures - sports and swimming pool halls Domed roofs Church spires Architectural features
Synthetic (and natural) rubbers	-	Electrical cable covering and insulation Damp-proof membranes Anti-vibration mountings Floor tiles and sheeting Carpet undorlays Flexible roof membranes Air-supported buildings Jointing gaskets Mastics
Various(PVC, Alkyd, PU etc)	-	Paints

Source: 'Polymeric Materials in Fires', CP 91/74, Fire Research Station and Building Regulations Professional Division, Building Research Establishment, Deptt. of Environment, Borehamwood, U.K.

APPENDIX II

List of plastics building products currently being produced and marketed in India

(i) Surface coatings-paints & Varnishes;

(ii) Resin-bonded wood panels;

(iii) A range of electrical fittings and lighting fixtures;

(iv) Electrical conduits in PVC and PE;

(v) Pipes and fittings in UPVC and PE, including taps, showers, basin, and sink-wastes, waste-trap, floats and syphons in polyethylene;

(vi) Decorative laminates for surfacing wooden furniture, and panelling;

(vii) PVC floor tiles (PVC-asbestos);

(viii) PVC coated wall paper;

(ix) PVC hand-rails, curtain-rails, staircase nosings;

(x) Epoxy-resin floor toppings for industrial floors;

(xi) Rooflight sheets in glass-fibre reinforced polyester resin (GRP)

(xii) Glazing and partition panels in GRP;

(xiii) Polyethylene film for water-proofing and damp-proof course;

(xiv) Bath-tubs in GRP;

(xv) Flushing cisterns in high-impact polystyrene;

(xvi) Thermal and sound insulation material-expanded PS;

(xvii) Concrete formers in GRP;

(xviii) Water-stops (water-bars) in PVC;

(xix) Chairs in GRP and polypropylene;

contd....

APPENDIX II (Contd...)

(xx) False-ceiling panels in GRP, high-impact and expanded PS;

(xxi) Window fasteners and stays in polypropylene;

(xxii) WC seats in urea-, phenol-formaldehyde, PS;

(xxiii) PVC leather cloth (including foam-PVC)

(xxiv) Vacuum formed PS Wall/Ceiling panels

(xxv) PVC extruded profiles for wall panelling/ partitioning/ceiling etc.

APPENDIX III

Expected Life of Building Components

1) Products with expected life in excess of 100 years.

Unreinforced concrete foundations

Bricks, roof tiles (concrete)

Reinforced concrete foundations

Internal walls (bricks/plaster)

Concrete wall slabs, and structural timber

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2) Products with expected life in excess of 50 years

Internal timber, aluminium windows, wooden flooring, lavatory basins, W.C.

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3) Products with expected life in excess of 25 years

Sink units, rainwater goods, mortar (lime) for painting, plumbing (copper, G.I., plastics), electric wiring; W.C. cisterns, tiling(kitchens and bathrooms) - cold water storage tank

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4) Products with expected life less than 25 years

Vinyl floorings
Plaster board ceilings (cracking)

External wood

Bitumenous felt roof

Boiler

APPENDIX IV

(Source: Progressive Architecture Sept. 1975, 86-90)

Technics: Plastics in architecture

Pandora's plastic box

All plastics are not created equal. As billions of pounds find their way into architecture, the designer's need to understand them grows. It can be a tough assignment.

There was something suspicious about the billiard balls. They were spherical, of course. But they collided with the sound of blazing pistols. The year 1863, and the billiard balls were made of an ivory substitute, nitrated cellulose, the world's first plastic. In the following century, plastics have found their way into 13 of the 16 sections of the Uniform Construction Index. However, learning what he needs to know about plastics remains a formidable challenge for the architect.

Architecture's appetite for plastics today consumes perhaps a third of the nation's annual plastics output of some 30 billion pounds. The architect is somewhat speechless in this success story. Like the father of the bride, he is awed, eager, and not a little intimidated

Plastics have generally remained on the fringe of his education. Even as he tries to comprehend the more familiar materials and methods of the plastics industry, new formulations and new products invade his building materials catalogs. In this brief inquiry, the plastics industry as represented by the Society of the Plastics Industry (SPI), tells P/A what it believes architects should know about plastics.

You look different with your clothes on

To the extent that an architect studies steel, concrete, wood and masonry he feels quite familiar with them. As well he should. Familiarity has bred respect for what these materials can and cannot do. The architect can afford an intuitive approach to their preliminary design and specification. He know "what a brick wants to do".

The architect's perception of plastics seems altogether different. Plastics bristle with strange and imposing technological barbs. They vary enormously in chemistry, physical properties, and costs. Their processing ranges from slow. simple, and inexpensive techniques to high speed, complex, a.. costly ones. Their nomenclature is necessarily uncompromising. A rose may be a rose by any other name; polymethyl methacrylate is neither the only acrylic nor the only clear plastic used for glazing.

Does this oblige the architect to be an amateur chemical engineer? The plastics industry thinks not. Inasmuch as a designer can create steel structures without applying more than an elementary knowledge of steel metallurgy, SPI feels the same should apply to plastics. That is to say, architecture is more concerned with design of the configuration of standard building components than with original designs for these components. Materials engineering is not an architectural responsibility.

And then there are fire losses involving plastics in construction. For the architect "burned once, never to specify again", this attitude may taste like a feast of ashes. If plastics chemistry is not his province and plastics fabrication remains an introductory lesson, how can he control the properties of plastics he must approve? Or are plastics really omnipotent?

Driving past the perpetual bloom of plastics frash landscaping our nation's highways, it is easy to forget that plastics are vulnerable to decay and destruction when improperly used. The SPI emphatically states that an all-plastics house is not an industry goal. There are situations for which plastics are most sensible, and those which are not.

The SPI suggests that performance specifications can give the designer his much needed control. What must the material do? This places a heavy trust in the manufacturers of raw plastics and finished plastics goods and the numerous private and public regulatory agencies, because the architect alone retains ultimate responsibility. However, an augmented architectural participation in plastics specifications may require an expertise the architect cannot exercise. The more unfamiliar and complex the intended end use of a building product wholly or partially constructed of plastics, the more valuable is the performance method of specification.

Sacred cacaphony

Architects have relied on "bibles" of design data for steel, wood and concrete construction for years, but there is not "plastics bible". In the absence of a single authoritative source of information on plastics engineering and design detailing, the architect is obliged to seek third party help. There is no equivalent body in this industry to perform the design services of an American Iron and Steel Institute.

American Institute ofTimber Construction, or American Concrete Institute, to name a few. As a result, the architect must identify reputable established standards for the plastics products he intends to use.

And who are these authorities? Consider that the faces of some of America's most prestigious testing agencies still bear the scars of spectacular fires involving plastics foam. Were there gross failures of judgment or deliberate connivance in these tragedies by the parties concerned? Despite the passionate arguments voiced then, this seems most unlikely. Rather, they were an accumulation of aggravations: poor building industry communications, optimistic readings of test data, and over-zealous end users. Trite as this sounds, not enough questions were asked by end users then. In the opinion of SPI, not enough are asked now.

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Dr. Albert G.H. Dietz, Professor of Building Science, Massachusetts Institute of Technology, outlines the basic plastics properties that immediately involve architects in his 'Plastics for Architects and Builders (1969)'. He lists: tensile strength, elongation, tensile modulus, compressive strength, compressive modulus, flexural yield strength, flexural modulus, hardness, impact strength, thermal conductivity, thermal expansion, resistance to heat, burning rate, effect of sunlight, clarity, and water absorption. This is a firm foundation of inquiry. More discriminating tools are needed, however.

Who are you? Where are you from?

A plastics product is only as good as the agency that approves it. A product lacking any such approval should be handled with extreme caution. The primary resource for the nation's plastics research and testing standards remains the American Society for Testing and Materials (ASTM). For those much bruited misunderstandings that arose like the Phoenix from ASTM fire tests D653 (Burning Rate, a test specific to plastics), E119 (Fire Endurance), and E84 (Flame Spread) to haunt end users have spawned extensive procedural reforms and the suppression of problematic terms like "self-extinguishing" and "nonburning" in product specifications.

Model codes, regional codes, and municipal codes, private and government research and regulatory agencies, and SPI provide specific design and specification guidelines and requirements to supplement what is given by manufacturers. The Building Officials and Code Administrators code, the Uniform Building Code, and the [illegible] Code are [illegible] of model code attitudes on plastics. Research data can be obtained from SPI, National Fire Protection Association, Factory Mutual Research Corporation, National Bureau of Standards, and Underwriters Laboratories.

Nonetheless, plastics also present the architect with problems currently beyond his control. Communication between the plastics industry, a diffuse group of large raw material suppliers and small processors and finishers, and the architectural profession is far from ideal.

(As Dr. Dietz notes, "The industry has the oddest notions of what architects want".) An industry organization specifically devoted to designers' needs is repeatedly requested by architects.

A plague of trade names further beclouds plastics design. As if the generic names were not enough, many manufacturers affix their own labels to the product. For example, polyethylene is simply "Polyethylene" for Dow Chemical, Eastman Chemical Products, Shell Chemical, Union Carbide, and W.R. Grace. But polyethylene also assumes a nom de plume like "Alathon" (Du Pont), "Ameripol" (Goodrich-Gulf Chemicals), "Chemplex" (Chemplex), "Fortiflex" (Celanese Plastics), "Hi-Fax" (Hercules Powder), "Marlex" (Phillips Petroleum) or "Petrothene"(U.S. Industrial Chemicals).

To complicate matters, certain trade names are joining the lingua franca as generic terminology. Formica, Plexiglas, Styrofoam, Fiberglas, and others. This list will undoubtably grow without decisive industry action. (It is also quite a tribute to the plastics industry, a reassuring measure of plastics pervading our lives.)

Memento mori

More life cycle and combustion data on plastics are sorely needed. Researchers have made significant progress; much remains to be done. One good step in this direction is the Urethane Safety Group of SPI, which investigates consumer safety and disposal methods for urethane plastics. We have a fairly thorough understanding of combustion theory now. What we need is an equally thorough analysis of actual hazard conditions.

Lacking a comprehensive picture of plastics in the environment, the architect is ill-equipped to organize negotiate life safety trade-offs. Generally, plastics are hydrocarbons (silicones are an obvious exception) as is wood. Thus, plastics combustion is an inescapable fact of life. But how much fire protection of plastics does society want or need? Is a plastic that resists burning only to succumb with thick toxic smoke preferable to another that burns cleanly but rapidly?

Paradoxically, a major problem for plastics is that the architect loves them too well. The profession has traditionally been a leader in innovative materials applications. This willingness to experiment with new products has ovvasionally led to unjustified and sometimes dire extrapolations from approved specifications. A skylight approved for isolated use becomes an entire domed environment, not always with offical sanction. The SPI believes that architects who wish to exceed strict, narrow interpretations of product approvals must subject them to an exhaustive analysis with the full cooperation of manufacturers and code administrators. A creative approach is not precluded.

Plastics are a remarkable family of building materials. Architects will undoubtably continue to specify them, often indirectly through building products that contain plastics in some form. But they need help from the industry for the hard questions society continues to fire at them.

Our ancestors searched for a philosopher's stone. Our generation has found one in plastics. In our iconoclastic era, it seems fitting that this miracle worker has its very real limitations. If the plastics industry gives architects it full support, we will continue to see creative uses of plastics in design. To quote Dr.Dietz, "Plastics are not wonder materials. Nor are they shoddy ones, either. There are few other materials with so many personalities". (Roger Yee)

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