OCCASION

This publication has been made available to the public on the occasion of the 50th anniversary of the United Nations Industrial Development Organisation.

DISCLAIMER

This document has been produced without formal United Nations editing. The designations employed and the presentation of the material in this document do not imply the expression of any opinion whatsoever on the part of the Secretariat of the United Nations Industrial Development Organization (UNIDO) concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries, or its economic system or degree of development. Designations such as "developed", "industrialized" and "developing" are intended for statistical convenience and do not necessarily express a judgment about the stage reached by a particular country or area in the development process. Mention of firm names or commercial products does not constitute an endorsement by UNIDO.

FAIR USE POLICY

Any part of this publication may be quoted and referenced for educational and research purposes without additional permission from UNIDO. However, those who make use of quoting and referencing this publication are requested to follow the Fair Use Policy of giving due credit to UNIDO.

CONTACT

Please contact publications@unido.org for further information concerning UNIDO publications.

For more information about UNIDO, please visit us at www.unido.org

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

D02797

United Nations Industrial Development Organization

Distr.
LIMITED
ID/WG.96/7
28 July 1971
ORIGINAL: ENGLISH

Expert Group Meeting on the Use of Plastics in the Building Industry

Vienna, Austria, 20 - 24 September 1971

SOME PROBLEMS ASSOCIATED WITH THE DEVELOPMENT OF THE BUILDING INDUSTRY AND WITH THE ACCEPTANCE OF NEW MATERIALS, COMPONENTS AND BUILDING FORMS.[1]

by

C.G.R. Hallam
Dipl. Arch., A.R.I.B.A.,
Industrialised Building Consultant
Leamington Spa, United Kingdom

[1] The views and opinions expressed in this paper are those of the author and do not necessarily reflect the views of the Secretariat of UNIDO. This document has been reproduced without formal editing.

id.71-5945

We regret that some of the pages in the microfiche copy of this report may not be up to the proper legibility standards, even though the best possible copy was used for preparing the master fiche.

SUMMARY

The demand for increased output of building and for higher environmental standards, coupled with a shortage of skilled labour is forcing the building industry to adopt new methods of construction and management. The new techniques of industrialised building use, as one of the tools, statements of physical performance and cost which must be met. We find, however, that we do not know enough about the physical performance, even of traditional building, to be sure of all of the standards we ask from industrialised building. The position becomes quite difficult when we try to understand and measure the things we like or dislike - our subjective criteria - as we introduce new materials and new building forms, and when we try to look into the future to decide in which direction to steer new developments.

I must speak as an Architect in English practice who is interested in the development of new building products and in the evolution of a modern building industry. It will be necessary for me to raise questions and to make suggestions against my background of the English industry but this is valid because building problems throughout the world are similar in principle and, as communications improve, the solutions will probably become more alike.

The modern building industry is seeking innovation by which, in broad principle, the existing craft-based method of construction is replaced by mechanical construction. The process is, however, slow and complex and it would be well to study it in some detail. I would like to break this Paper into two main subdivisions, the first dealing with the problems of innovation and the introduction of new materials and new building components, the second dealing with the physical and mental or emotional questions which may follow and how these may affect the people who use our buildings. As a matter of convenience it is necessary to discuss the above questions separately in this Paper but in practice must be seen as parts of the total building problem, all contributing in greater or lesser degree to the understanding of the environment which we create by building.

THE INTRODUCTION OF NEW MATERIALS AND NEW BUILDING COMPONENTS

We must take for granted that the demand for building is outstripping supply and that the problem which needs to be answered is how we greatly increase the production of buildings. This could be attacked within the traditional building industry firstly by increasing

increasing/
the supply of building materials, secondly by increasing the number of skilled building craftsmen and thirdly by raising the craftmens productivity. The fact is, of course, that traditional building methods cannot provide the answers and that new forms of building are required. As example of the difficulties facing one basic traditional building trade will be sufficient to show the total dilemma. It is possible continually to improve the manufacture and distribution of bricks but, although bricklaying is a highly labour intensive operation we are not continually able to increase the supply of bricklayers. If the large building growth rate is to be maintained it is necessary to increae the productivity of each bricklayer but it is not possible, beyond a certain point, to increase the number of bricks that a bricklayer can lay by hand per day. Any further increase in productivity can only be met if we change the craft process or introduce a new method of building. The solution adopted is to change from traditional to industrialised building, that is to change from a labour intensive to a capital intensive industry; from using many small cheap building components placed on site by skilled labour to using few large expensive building components placed by mechanical means and requiring the minimum of labour.

<u>The problem of innovation</u>

The complete revision of building activities and responsibilities which is now brought about must be considered briefly. I will discuss the responsibilities of the main participants in the building sphere, namely, the client, the architect, the contractor and the component supplier, firstly when conducting traditional building and secondly when conducting industrialised building.

In traditional building the client usually wants a single contract. The contracts vary in size from one building to an estate of buildings but in principle the client intends to do a limited amount of work, the contract is agreed on this basis and at the end of the work all of the accumulated skills are dispersed onto other contracts where they reform in a different pattern. The client provides to brief, the finance and usually has a site available. The architect is retained for one contract by the client on a fee basis to design the building, select the contractor, supervise the work and to agree the accounts. The contractor is engaged and paid by the client and is responsible for all direct building work and sub-contractors. The component supplier is engaged and paid by the contractor for common building products but is engaged by the architect and paid by the contractor for special components.

Within the above relatively unsophisticated industry it is possible to maintain good communications and building operations can remain efficient, even when providing an individually designed building on a unique site every time a contract is placed. There is an understandable wish not to move from the above established positions and innovation is slow. The client as a rule builds only once and primarily needs a cheap well designed well constructed building. He will not welcome being the 'experiment' which will probably only benefit the contracts which follow his own and he probably realises that he stands a greater chance of building failure than if well-trodden paths are followed. The architect prepares drawings and specifications suitable for a competitive tender. If he changes materials and

materials and/
components or if he introduces techniques which require a new method of building he may succeed only in raising the cost of his ideas against traditional design. If an architects proposals fail he may well be sued for damages and could lose his professional reputation. There is no connection between architect and contractor at the vital early stages of design and information concerning design requirements, new construction methods and costs cannot be exchanged. Once the contract is let the building must be started and there is rarely time to revise the design. The contractor tenders for a large number of contracts but succeeds in only a small proportion. He keeps his organisation flexible in order that he may build a wide variety of building types. He has no desire to invest in special equipment for one contract when it is unlikely that that he will be able to use the equipment again for a long time. The component manufacturer produces articles which are in large, constant demand such a bricks, windows and doors. These components are fairly small and can easily be handled on site to be incorporated into the building without imposing any design restriction. There is no incentive for the component manufacturer to sell large, heavy constructions such as pre-finished wall panels or floor panels because he has no way of knowing the sizes, contours, materials, colours or numbers which are required. He will not know what manufacturing, financing or stock-holding methods to adopt.

The industrialised building industry

The new, industrialised building industry has been developing for many years but is only now entering its most progressive stage. It is necessary briefly to restate the aims and intentions of industrialisation and to follow changes of activity within the building team which follow, as it is only from this platform that we can anticipate the probable future trends of building and see how best we can marshall our forces to attack the problems of even larger scale building.

The site handling and assembly of components can be mechanised when there is a constant supply from the component manufacturer. The advantages to the contractor are that his labour force can give better productivity per man, the work is better programmed, labour is better controlled, less capital is tied in unfinished work and capital is turned over more quickly. When component manufacture is mechanised, workers who would not wish to go to building sites can be-recruited into the factory for making building products and thus build up a greater total labour force than would be possible under the traditional system; the factory can obtain the highest productivity from these people through large scale production; a new range of materials and components become available which would not be availble from traditional sources - which will give greater variety and interest to the buildings using these products; the components can be made to greater accuracy and to higher standards of finish than can be obtained on site. It is clear that transport between factory and site must become an integral part of the complete building operation which operation which/

begins in several factories but ends on one site many miles away.

Research and development is possible under large scale building operations because development costs can be distributed over a large number of components. It is also possible to combine skills in multi-disciplinary teams which would otherwise remain isolated, so that architects can contribute for building design, component design and environmental problems; engineers can contribute for manufacturing problems; contractor for site management problems and building costs. It is necessary, of course, to consider the full range of the development problem which extends at the one end from the physical characteristics and manufacturing needs of materials through the manufacture and test of building components to the erection, test and costing of complete buildings. Each stage of costing must be comprehensive so that the full economics of the finished building is correct - for example each component must be costed at the optimum output level and an adequately large building contract should be considered. It is clear that a factory produced component will be more expensive than a site produced component because of heavy factory overhead costs, transport and mechanised site handling costs. The site savings are found in the good use of site labour, quicker capital turnover etc, already mentioned. It is clear, also, that the costs of installing mechanical site handling equipment can only be offset on large contracts; the greater the quantity and the more sophisticated the equipment the larger the contract must be. The architect is faced with is faced with/

new disciplines in his design in order to achieve the advantages of construction speed, raised standards and a known cost. He must plan his buildings to agreed dimensional increments, reduce variety of materials and components, preplan the whole building operation before the contractor starts work on the site and never change his design once the building has started. He must plan his building in sympathy with the way in which the contractor will assemble it. The client obtains a building of raised standards, at a cost which can be estimated at a very early stage in design, and built much more quickly than would be possible traditionally.

<u>The new lines of communication</u>

The old, traditional communication is not suitable for a new high powered industry. The methods of communication had been worked out by a common understanding of hundreds of years duration, a form of shorthand was possible. Two short lines on a scale 1:100 drawing represented either a window frame of a door frame. A short written specification would describe the article and, within narrow limits, a satisfactory article was obtained by the contractor. If something special was required the architect drew larger-scale details. The same principle would be applied to all parts of the building and the architect was able to specify the material form of his complete design. The architect and builder already knew the performance of materials and of components because of large usage and experience.

As we change to the use of industrialised components we need a new method of communication which will which will/

encourage innovation and also help people at present outside the building industry to offer their skill and expertise. Instead of specifying the material form of the component, we specify the performance which the component will be expected to fulfill in use and also state the anticipated cost of the component when fixed in place.

Performance specifications and cost target

The performance specification for an external wall panel will state the shape and dimensions of spaces to be filled, the degree of resistance to air penetration and to water penetration, the degree of thermal resistance, the strength against wind loads or physical impact, the degree of resistance to sound transmission, the fire resistance, the requirements of jointing to other components and so on. The cost target is the estimated proportion of the total building cost which can be allocated to the component. This figure is very important because it allows realistic breakdown into manufacturing, transport and site assembly costs. Most important it allows components to be completely redesigned - for instance it is possible to use an expensive material such as one of the plastics family which may lead to a high component manufacturing cost but may save cost in transport and site assembly due to the lightness and ease of handling of the finished components. The manufacturers are encouraged to quote for long production runs to that the maximum benefits are obtained for all concerned. It is important to state that no attempt is made by the writer of the writer of the/

specification to answer all the problems he poses. It is intended that the manufacturers should use their own skill and experience in suggesting solutions.

In its most direct use a performance specification is the basis of a shopping list against which a prospective purchaser can measure the components already available on the market. Secondly the specification can be used to upgrade existing products to the necessary standard. Thirdly it can be the basis for the development of completely new components.

It is interesting to consider how far the prime movers in the industrialised building industry may change; changes which are taking place alongside the unchanging positions of the traditional building industry. The clients are now the large Government Departments, Local Authority Consortia, Hospital Boards etc. who can organise large markets, give long contracts and will encourage innovation because they will reap the benefit of it. They also have adequate building programmes which will accept standardsation of dimensions and reduction in variety in components. They must, however, always remain the ultimate buyers of buildings. The architects now help to a greater extent to formulate the brief for buildings, they engage in close working with other skills in multi-disciplinary teams, they engage in research and development into new materials and components. They may yet enter contracting. The contractors are moving towards the assembly of components, with reduction of traditional skills.

(Traditional skills are still retained because many parts of the building sequence have not yet been rationalised but the goal must be that the contractors only erect on site the prefinished products delivered to them.) At present some contractors also manufacture components but it is doubtful whether this activity can be continued indefinitely as component manufacturers become more organised and more competitive. The compnent manufacturers are encouraged to develop new products which are larger and more complex than before. They still make a range of products, on the basis of the safety of diversification. They tend to produce in large batches and they also often offer a "supply and fix" contract. Both of the above practices are inefficient and the ultimate aim must be that the market becomes large and stable enough for manufacturers to specialised in very few products which are constructed on flow-line principles and all site fixing should be delegated to the contractors who would become specialist assemblers. The logical extension of this work is that the building industries of the world can co-operate in the exchange of knowledge and in the sale of building products to a much greater extent than has been possible so far - this brought about by the international acceptance of standards of dimension and of performance.

The implications of large scale production for plastics in building

It is interesting to consider what the next developments in plastics in building could be.

It is necessary to presuppose certain requirements - for instance the market must be extremely large and stable, there must be adequate resources for a large, sustained research and development programme before any production is put in hand there must be confidence between all parties concerned that the project will not be stopped once production stage is reached and so on.

I must take for granted that another paper will deal with the physical properties of plastics and their methods of manipulation so that we are able to concentrate upon their use in buildings. We must also accept there is much wider building application than plastics in housing but that we wish to concentrate our efforts upon this one building type. The first question upon which we need information is that of the users' needs because this will dictate the whole course of the development programme. A performance specification would be used as a guide to or as a definition of the user's need, so that certain physical and climatic statements can be accepted and other social criteria can be recognised.

The second question we need to answer is the basic direction from which we approach the development of products. This problem revolves around the conflict of component building versus single unit building but this is not a simple question of market size and production numbers and is worth further thought.

Component building

The advantage of component building are: that the various components can be mass produced so that the so that the/

best cost per article can be obtained; that the relatively small standard components can be assembled in a variety of ways in order to achieve flexibility of design; that a house can be replanned internally without difficulty and that a complete house can be stripped and re-assembled if the need is urgent; that other materials and other components can be used in association with plastics components; that whilst it is possible to use long life components it is possible to achieve short life building without waste. The disadvantages are that the jointing, fixing and handling methods are liable to damage during transport and assembly; that the jointing systems of otherwise impervious components are subject to exacting conditions in use and are often the major point of failure; that a high degree of skill is required on site to properly assemble the parts and this is not always available; that whilst the components can be manufactured as cheaply as possible, some cost is introduced by the employment of site assembly labour; that we are only using "large bricks".

Single unit building

The advantages of single unit building are; that efficient design and best utilisation of materials is possible because of monococue structure; that site assembly methods give the most efficient use of scarce or unskilled labour. The disadvantages are; that transport is expensive due to the bulk which is carried; that furnishings and fittings would need to be special and probably built into the curved structural shell; that the house could not be stripped and re-planned during its life.

Parallel problems

Points which must be considered in parallel are :-

the anticipated life of the houses and how they will be bought; if Government owned , over what period there should be no maintenance and over what period the houses will be amortised; if privately owned, whether the house should be regarded as a capital asset which appreciates in value as does a traditional house or whether the house is a consumer durable which depreciates as does a motor car; whether the purchase money is borrowed as a mortgage or as a hire-purchase agreement; over what period these loans would operate and under tax concessions.

THE MENTAL AND PHYSICAL ACCEPTANCE OF PLASTICS HOUSES

Mental acceptance

It is necessary to digress briefly to consider what we mean by 'building' and 'environment' and see how they inter-react. Building can mean a process of construction, the art or science of construction or the place which has been constructed. It can be a single building intended to provide simple shelter from the elements or it can be a city in which men can undertake complex activities. The environment can mean an envelopment - as in the case of an internal environment created within a building or it can mean surrouding - as being surrounded by the external environment created within a city. Buildings provide spaces within which to conduct activities, either on the inside or on the outside of the buildings and there need be no differentiation

differentiation/

between internal and external environmental spaces. As a shelter, buildings provide acceptable physical conditions within which to conduct activities; this means that the buildings regulate rain, air, light and extremes of temperature. However, different activities require different spaces, coupled with different physical conditions. For instance, a sports arena built for a wide variety of activities may require large cool spaces and small cool spaces for active sports but also require large warm spaces and small warm spaces for conferences etc. Thus 'building' and 'environment' are completely intertwined and cannot be separated. Good building not only aids our activities, it enriches our experiences and adds to the quality of our lives.

So far, in the discussion about the use of performance specifications, we have considered the measurement of physical standards in building and the preparation of a new building industry which is capable of enourmously increasing the output of products. We are in a very delicate position because if we now mass produce the wrong articles we could face the catastrophic ruin of our environment. We must be careful that we build an environment which will satisfy our mental and emotional needs but this is largely a subjective matter and difficult to measure in the way in which we assess physical needs. It is possible to meet this problem when developing

when developing/
products which we think we understand. For instance, a hypothetical component manufacturer could take a performance specification describing a component which separates the interior environment of a house from the exterior environment by excluding the wind and rain, by reducing extremes of temperature difference, by reducing sound transmissions but which will allow controlled ventilation and permit vision out from interior to exterior and vice versa. The manufacturer produces his 'Window' which answers the above specification perfectly in every way but for reasons of structural strength has been made Gothic in form. The architect refuses the design simply because it does not suit a modern building; because it offends some aesthetic sense. It is important that we try to understand our subjective criteria. We must try to be in a position at which we can quantify; possibly to put a numerical value in the same way that we can for physical criteria. This information should be added to the specification, possibly in the form of design constraints. It is difficult to know the direction this work will take because the different backgrounds and circumstances of those who use our buildings play an important part in what they will accept.

It may be that a great deal of the physchology of acceptance depends upon security. One person may well have different values in different circumstances and be quite secure in each circumstance if they are taken individually. A successful business man may be a leader in

a leader/
in his sphere of activity, he may work in a modern office surrounded by all the latest business aids, he will happily fly around the world in the latest aircraft but at home he seems to need a different environment. He often buys a converted old house or buys a modern house of old character. Does he need security ? If so, of what form ? Does he need an anchor ? If so, what type ? It is improbable that, as a wealthy man, he is preoccupied only with resale value. We can try to find what visual security is. Suppose we walk along a street in Europe and we become accustomed to the street pattern. With good architecture and fine townscape in which all of the buildings act as good neighbours we enjoy our experience. If, suddenly, we are confronted by a different type of building, say, an Oriental temple we experience a shock. Do we dislike the intruder because our security is disturbed ? The same would apply to seeing a European building in an otherwise Oriental setting.

We are now at what I think is the most important consideration of all, that we build for people. We must be sure that wherever mass produced buildings are used they will be acceptable to the people concerned. It is a waste of time thinking that physical shortage is the only problem in the developing countries and that this can be overcome by sheer large scale production. We must be sure that we fulfill the mental or phychological needs as well. We could be in danger of thinking that thinking that/

our technological superiority will allow us to superimprose our ideas onto different peoples and cultures. By all means we can offer technological help but the cultural requirements must be at the discretion of the users. There are further problems which present us with a moving target. We may try to fit our suggestions against a background of todays social and cultural needs for any community (recognising that our suggestions are not suitable for all communities) but new sociological patterns are emerging within developing countries which may render buildings obsolete as soon as they are erected.

Let us think more closely about plastics houses and the problems of their pyschological acceptance. Taking the interior first, we could define building as an arrangement of space or spaces within which people carry out their activities. There must be space for articles and space for movement but there is infinite variety in the combinations of these. In addition to recognising that space costs money and that space can be wastad if it is either too large or too small for the activity for which it is intended, it is necessary to discover how people live, to understand the functions of their society and to appreciate the way they use space in order not to cause offence and thus the rejection of our ideas.

With component building the standard interchangeable

interchangeable/

parts would probably be rectangular in their outline and with reasonably flat surfaces because this is geometrically necessary for the interchangeability and flexibility in use. It should be possible to provide a set of components which are physically capable of withstanding the extremes of climate from the tropics to the Arctic (provided cost is not all important) but clearly a practical suggestion would be to limit components to certain zones of climate. It is not easy to decide whether we can isolate cultural and social zones in the same way, and whether they coincide with climatic zones. However, accepting the above questions, there is a good chance that component building will provide enough variety in form, material and colour to suit most aesthetic needs and that the flexibility in assembly will permit the erection of buildings suitable for most social and cultural needs. If the needs change it should be possible to re-assemble the components.

With single unit building the monocoque shell would probably be a continuous curve because this is structurally necessary, although the curve could be modified to give areas as flat as possible for the surfaces usable as the floor, walls and roof. The units could be limited to climatic zones but there is an interesting additional question about the psychological acceptance of curved surfaces. We know that our environment must not aggravate us and in this way the Africans who use round huts could accept rounded living quarters more easily than Races who

Races who/
have become accustomed to flat surfaces and angular corners.

Thinking now of the exterior of our houses, that is, our townscape, we have a similar set of problems. There is strictly no division between the spaces inside and outside a building because there is no division in our activities. Whether a building registers a division because its envelope is opaque or whether it does not because its envelope is transparent is at the discretion of the designer and the user. We consider usable space to flow according to our needs but for the sake of this discussion I would like to consider only the external spaces or environment we experience and observe when we are surrounded by opaque objects.

The environment created by component building will be acceptable to many people because the individual buildings will present fairly flat facades or will be seen as more-or-less rectangular cubes, also the spaces around and between the buildings will be rectangular. It will not be difficult to obtain continuity between buildings or groups of buildings because of the simple geometry of the components. It should be possible to design upwards from a single dwelling to a layout of hundreds of dwellings and obtain good satisfactory townscape. Single unit dwellings pose a different problem. An African hut or a near spherical plastics house can look magnificent in isolation on a selected site. A few huts can be placed close together, either with the huts separate from their neighbours or

neighbours or/
joined by low screen walls and still maintain their character and provide a fine environment. It is difficult to expand this concept indefinitely into the form of a large town. This is not to say that it is impossible. It could well be that single-unit plastics houses would provide an environment of great richness and interest. Clearly much work must be done to try to understand what makes some things acceptable and others not - to find where good design stops and crudeness begins - to discover where common denominators lie - most important to discover trends in attitude so that we can anticipate what will be acceptable in the future so that development work is not abortive.

Physical acceptance

We in the building industry do not understand traditional building as well as we could. It has developed by trial and error over a very long time and the failures, gradually, have been corrected and built into a code of activity - some written down in the form of building regulations and building standards but much still used simply because it is "good practice". Sometimes good practice lets us down when it is applied to a new situation - for instance - on low buildings we take it that rain falls downwards and that, when once on the building, the water continues its downward journey. We detail our buildings at roofs, gutters, windows and doors to throw the water clear of openings. On large tall buildings, however, tall buildings, however/

the bulk of the building can force the wind to blow upwards which carries the rain and the water on the surface of the building upwards with it so that the traditional methods of keeping the water out of the building are no longer suitable and new details have to be developed.

Traditional brick and stone building has mass which gives it inherent strength and stability, resistance to sound penetration, resistance to fire penetration, strength against accidental damage, it resists water penetration but allows passage of water, vapour and so on. We have a good balance of desirable physical properties at our disposal and we have design freedom to vary any one of them without unduly upsetting the rest. For instance, we may decide that a building is too cold in winter and we wish to raise the temperature of our rooms by a certain amount. We can measure the heat loss through the walls and inject suitable insulating material into the wall cavity. We know that we will not change the water vapour permeability of the brickwork so that we should not worsen any condensation problem - indeed we should lessen it because we are raising the room temperature. When concrete wall panels were introduced some years agothere was unexpected trouble with condensation because, whilst the heat insulation had been raised to above that normally obtained by brickwork it was not appreciated that the concrete was less permeable to water vapour than was brickwork. The consequent build-up consequent build up/

of vapour within the buildings led to serious localised condensation at any point of reduced insulation and at any 'cold bridges' in the construction.

As we increase the proportion of new materials which we use alongside traditional construction we find that there are aspects of construction which must be observed carefully in order not to fall below acceptable standards of building. This becomes even more important as we consider buildings made completely of non-traditional materials. Some of the qualities which we appreciate and some of the dangers we see in plastics are given below. This is not intended to be a comprehensive statement but at least it shows an architects attitude. Plastics components can be light in weight and easy to handle. They should be able to achieve adequate strength for, at least, housing needs. They can provide good heat insulation, good water resistance and good weathering. They can provide translucency as an integral feature. Plastics can lead to new design forms. The disadvantages cover poor sound resistance, poor fire resistance, poor vapour permeability, poor abrasion resistance and high cost of materials.

We can probably say immediately that physical acceptance is assured on the basis of adequate heating, ventilation etc. but that design implications are less certain and that this subject needs further consideration.

Design implications

In the previous sections I have dealt with some of the principles of the measurement of criteria and their use in performance specifications, also I have mentioned some aspects of subjective criteria which are, at present, impossible to measure. In the next sections I want to delve a little into the thought processes of building design and development, firstly to question aspects of design which are contained within us and may unwittingly lead us to incorrect conclusions, secondly to look a short way into the future with a typical building construction problem. The problem is the provision of services in houses and I wish to question the inter-relationship between the supply of water, sewage and electricity also to question the development of house shells in order to see how ideas upon one can impinge upon and alter the others. The difficulty we face with the above trains of thought is that, whilst we can measure and specify the performance required by a new product about which we have had some experience (say a roof panel) we cannot accurately specify the performance of anything about which we have insufficient experience. One way out of the difficulty is to present a hypothesis and subject the hypothesis to test. My following suggestions are intended to be pointers to the way in which such a project could go. By design I mean the welding of mental or emotional needs with physical needs into the final product. Naturally the characteristics of the material which is selected, the manufacturing method of the product, the site assembly method assembly method/

of the building etc. are taken into account in the total assessment.

Plastics have been widely used in many products but, still, insufficient is known of their performance in use. Some of the following questions could probably be answered now but many still relate to future patterns of activity in the building industry and the answers must be sought from first principles in the climatic and cultural zones in which the products will be used. The questions must be answered carefully because they are the basis of future activity (which means time and money, both of which are too valuable and necessary to waste) The initial answers must be at least 75% correct. The remaining 25% deviation can be corrected or studied in greater detail during the course of a development programme. If the initial answer is less, even, then 50% correct it becomes extremely difficult to obtain satisfactory results, however good the subsequent development work may be. The quote an old English saying, when you dig a hole you must be sure that it is in the correct position because if it is not, the harder you dig the worse your final problem becomes.

We have discussed the fact that new materials can lead to new structural shapes, which can in turn lead to new building forms. We know, also, that plastics are expensive materials so that there is probably a cost penalty in their use in most building components. It would be well, therefore, to start our design study on the basis of cost and the efficient use of materials.

We probably face any design problem full of our own prejudices and misconceptions. This is the inertia of our own backgrounds which spreads from far beyond our own lives and is intermingled with all we see and contact. For instance, houses built 100 years ago are huge by todays standards, 100 years ago the families were larger, there was a more strict social order to uphold and there were large numbers of house servants who could be employed to maintain and run the establishments. Nowadays families are smaller, there are no servants available to be employed and new social patterns have removed the need for an imposing house. However, we find that the internal planning of modern small houses has not changed drastically. There is often a separate kitchen, which may well be left over from the attitude that kitchens are for servants and must be segregated. If the kitchen is coupled to a living room it is only to the dining room and not to the lounge. We should question the whole basis of modern family life in which all members contribute to common good and yet in which the person working in the kitchen is put into isolation. Similarly we should question the modern social pattern in which visits to friends and neighbours has been replaced by television viewing. The effect upon older children has been that they are expected to study and work in their bedrooms but most bedrooms are designed to hold only beds and wardrobes, and are unsuitable as study-bedrooms. This re-designing need not take any more space and need cost no more money. It is a matter of deciding the priorities of activities and re-allocating the areas.

If we apply the same design processes to plastics houses we could even save area, reduce materials content and save cost without sacrificing good standards. For instance, many kitchens are too large so that apart from the wasteful building cost the housewife is constantly engaged in unnecessary movement in the most intensely used part of the house. It would be valuable to obtain data on anthropometrics, activities, processes and social needs from a wide range of sources and plan a few suitable standard mass-produced kitchens. It would be possible to undertake comprehensive design - for example - in a single unit building the curved walls need not be a disadvantage when fittings such as cupboards can be integral. Indeed it may be possible to make use of the varying dimensions to give increased efficiency in the use of space.

It would be interesting to look forward a short way to see some of the advances in design which modern technology can bring. In the developing countries I assume that the great advances are in the supply of fresh water, the supply of electricity and in good drainage with sewage disposal. These are basic to good health and to advancement. These commodities will be in short supply and the best use should be made of them. There is a direct relationship between water and sewage. If water from sewage is allowed to run to waste it amounts to an inefficient employment of a vital commodity and, as consumption rises, more and more new water has to be found.

There are two methods of attack open to domestic water users - the first is to use less water; for instance, by using sprays for washing and bathing it is possible to cut consumption down to 1/6th of that needed in basins and bathtubs. An even greater saving is possible by using spray-mist when the consumption drops to about 1/10th. The second is by the re-use of water where possible. Supposing that a method of sewage purification could be fitted within every house, the water could be re-used for crops. If this is not possible but non-waste purification becomes available for groups of houses the water could be re-used for industrial processes. The design advantages are considerable. The shower or spray cubicle is much smaller in area than a bathroom and there - fore cheaper. The re-use of water allows greater freedom in the layout of groups of houses or in towns because the water can be returned to mains and pumped. This overcomes the restrictions imposed by gravity sewers where the sewage treatment works must be at the lowest point possible and towns planned upwards from this. A supply of electricity would make possible the electrolytic purification of sewage, but there are others commercially available. Electricity could be the main source of energy for providing environmental comfort and a number of interesting facets spring from its use. Heating need not be provided from a traditional small high-intensity source but from a large low-intensity source which is embedded into the surface of walls or ceiling. This method gives better distribution of heat and is less subject to accidental damage.

Electric lighting will be required as environmental and education standards rise and much work must be done upon the relationships between lighting standards and quality of vision so that the most suitable lamp types and lamp positions are known. In certain buildings it may be required to instal high-intensity illumination at, say 500 to 1000 lux, at which levels the heat emission is considerable, and it is possible to collect this heat to be used for space heating, thus economising in heating plant and running costs. More research is needed into the relationships between light intensity, quality of light, good vision, power input and heat produced. In the various regions of the world there is an infinite variety of climate between cold and dry, cold and wet to hot and dry or hot and wet. Information is needed upon the requirements for comfort conditions in any of the permutations of climate - for example, we must know the relationships between heat and air change, humidity and condensation so that we can obtain the correct ratio for comfort in any circumstance, and design both the building and its heating or cooling method in harmony with the need.

In previous parts of this Paper, when dealing with the development of components, I have mentioned the need to consider the materials used, the manufacturing method, the transport and the site assembly methods as constituent parts of the whole operation. The reasons for selecting a particular component may be the cheapness of the installed product or the speed of assembly or the use of unskilled labour etc.

These principles apply to work carried out below ground level as much as to work above ground. Let us consider drainage, water supply and electricity supply and see how these could change under the influence of plastics. Water supply normally is taken through trunk mains for large rural areas and for towns and divided to local mains for streets or groups of houses. The mains follow the contours of the land. The materials are cast iron or P.V.C. Drainage works entirely differently in that the small drains from the houses lead into small sewers for streets which lead to trunk sewers for large areas or towns, discharging into the sewage works. The gradients fall constantly towards the sewage works. The materials are stoneware glazed pipes or concrete sections. Electricity is carried at high voltage above ground for long distances but when it has been transformed into low voltage for domestic use it is carried the remaining short distance below ground. These three services are kept separate because of the fear that sewage could contaminate water supply, because the level of the pipes are rarely constant, and because electricity and water are poor companions. If it were possible to develop high efficiency domestic sewage treatment plants and return the purified water to a second water main, we could extrude a double main which would be laid as one unit and follow the land contours. One main would feed the houses whilst the other would feed the farms or factories. The cost of the domestic sewage treatment plants could be offset against the usual astronomically high costs of laying deep sewers and building public sewage treatment works.

Whether or not it would be possible to extrude low voltage cables and telephone ducts integrally with the water/sewer main is not certain but it is worthy of more consideration. The principle, once proved, could be used between the mains and the houses. Standard junction boxes could be fixed on the main and the feed taken by a small set of extruded tubes to the individual houses. Of course this rationalisation of site works would include simplification of foundations, because the complete building assembly operation must be co-ordinated and any one slow or uneconomical activity could jeopardise the whole operation.

PUTTING THE PRINCIPLES INTO PRACTICE

I would like briefly to discuss the principles of a project upon which I am currently engaged for the development of external cladding wall panels, and see the advantages as well as the limitations in the use of performance specifications. I will mention no names at the request of one of the companies involved but I will be pleased to discuss any items privately should anyone be particularly interested.

The sponsoring company is interested in the sale of plastics for use in building but recognised some years ago that the building regulations and current building practice inhibited the use of plastics in any situation which included fire resistance, structural strength or sound resistance. The Company decided

The Company decided/

that if 100% plastics structures were not yet feasible, that composite structures would probably overcome the major acceptance problems and, taking sandwich construction, it would be logical to develop a semi-structural, fire resisting, lightweight, heat resisting core to which plastics facings could be applied. It was intended that the new material should be only a stop-gap for use in association with plastics and that its purpose was to develop confidence in plastics in building users and help towards the increased use of plastics in building. It was not originally intended to continue its use once the building regulations were modified, new plastics design concepts were acceptable or better plastics were available. However, it is interesting to see that once again, whilst development work is expensive it pays its way. The Company has now started to sell the core material for applications in traditional building for which it was not originally envisaged and to earn Royalty by its use. Two parallel lines of development are now in hand, one for products employing plastics and the other for traditional products.

Returning to a development programme which employs plastics, the Company agreed that a good avenue of investigation would be in industrialised building because of the large potential market in standard parts. We persuaded a Hospital Board to co-operate with us as a client, because the Board knew the knew the/

functions and activities carried on within its Buildings, and could provide us with a performance specification of the physical standards to be met by the panels, also the Board could provide a cost target for the panels fixed in place. Finally the Board agreed that if we could meet their requirements, they would buy an agreed number of prototype panels to be fixed in a normal 'production' building, and the building would be observed for an agreed time. Any faults could be investigated and the information fed into refinements for the subsequent production runs of panels. It was, of course, necessary to invite a plastics manipulating company and a building company to pool resources in the development because the range of skills required goes far beyond that possessed by one individual person or company.

A work programme was agreed, which laid out the dates by which certain phases must be complete, but much more important laying down places at which because of some failure to reach a performance standard, the project could be temporarily halted until the trouble is corrected or at which the whole project could be declared abortive.

So far the project has again proved the value of the use of performance specifications and multi-disciplinary working which other development teams have reported. I am particularly interested in the good communication which exists where the Boards architect (that is, the clients architect) can discuss aesthetics, general building design and other subjective criteria with me, as the manufacturers architect, and ensure that after answering the quantitative aspects of the performance specification the work will not ultimately be rejected on the grounds of appearance.

As I mentioned elsewhere, a cost target is the estimated cost of a component fixed in place when taken as a proportion of the total building cost. It is a guide only and is not intended to be a fixed sum which must be reached. The cost target for wall panels in housing, for example, is about £6.00 per square metre whilst that for some school building if £9.00 per square metre. In practice the quotations for all components are obtained competitively and probably the actual costs on both building types will finish much the same. However, the cost target does stop a Company from going ahead with development if they find that their prices are going to work out exceptionally high and they have no other advantage to offer to offset the high initial cost.

Conclusions

Performance specifications have been introduced into building only recently and much more has to be found out about their use and abuse. However, for at least the foreseeable future they will be used as a means of communication between people of varying backgrounds, skills and interests in the furtherance of modern building.

13. 3. 72