8

Materials
Albert Dietz

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I might start off by saying that a great deal of what I was going to say has already been said, but I'll have to repeat some of it just the same.

First, I want to make a few general observations. I don't know of any new or revolutionary materials that are being used now or are immediately in sight, unless the space industry comes up with some surprises.

That depends, of course, on what is meant by "new" and "revolutionary." Some people might consider that some things I want to talk about are new and revolutionary, but to me they are not. They're in the evolutionary stage. They may have been considered new and revolutionary fifteen, twenty, twenty-five years ago. They are now going through the stages that every new material has gone through, the long, slow process of development and acceptance by the industry.

Masonite took about twenty-five years to become a broadly accepted commodity. Gypsum board is another instance. Even portland-cement concrete had to go through a long period before it was generally accepted. That's been true of building materials right down the line, and it's true of the materials we're talking about today.

We can't discuss all materials. I'm going to concentrate as a case on the new group of materials and composites based on polymers. I might review, however, very quickly some of the older types of materials.

We have structural, nonstructural and auxiliary materials: Structural being those that carry loads, including steel, concrete, timber, masonry; nonstructural, such as flooring and insulation; and auxiliaries, those materials such as adhesives, sealants and coatings, which are used in conjunction with other materials and may not be seen at all. There are developments in all of them but they are not particularly revolutionary.

Another classification of materials is non-metallic, metallic, organic, wastes and byproducts. Developments are occurring in all of them but none really revolutionary. There is one area, however, in which a great deal can be done, and in which there are real opportunities, and that's in waste and byproducts. We're tearing our cities down and having a terrible time trying to find out what to do with the rubble. We ought to be doing a great deal more to determine how we can reuse that rubble rather than throw it away and bury it somewhere. That's a tremendous challenge.

Byproducts are another great challenge. If and when we ever solve the sulphur-dioxide emissions problem, we're going to have millions of tons of sulphur in one form or another, and what are we going to do with it? Byproduct gypsum is one possibility, for example, and there are many others. Sulphur can make a very good concrete. It can also make a very good road building material. There are many wastes and byproducts, obviously, in which we ought to be doing a great deal more than we are, agricultural wastes, for example.

The wood industry has gone a long way. What used to be considered wood waste and was just burned because we didn't know what else to do with it now goes into chipboard, a very valuable product. We're using waste species we never had any use for before, making them into strandboard and other boards, valuable products. These boards were made possible by the advent of the high-strength synthetic adhesives. This introduces the field of combined materials, or composites, the subject I'd like to concentrate on.

What types of composites do we have? I'd like to put them into three principal classes: particulate, in which particles are embedded in a matrix; fibrous, or fibers embedded in a matrix; and laminar, composed of sheet materials, bonded together and possibly impregnated. Under laminar, is the special subclass of sandwiches.

The most important particulate building material is Portland-cement concrete, It has its limitations, and by adding polymeric materials, we can come up with some rather striking improvements.

The first approach is to impregnate standard concrete with perhaps five to eight percent of a material such as acrylic, to produce a three to fourfold increase in compressive strength. Going from 5,000 to 20,000 pounds per square inch has not been unusual. Hardness also goes up, as does resistance to impact. Resistance to freezing and thawing increases because the pores have been filled. The difficulty is it's a slow, arduous, expensive process, requiring autoclaving or other means of impregnation and curing.

The second approach is to incorporate the polymer while mixing the concrete, with variable results, some very good and some very poor.

The third, is the substitution of a polymer for the portland cement. In other words, concrete is bonded with a polyester, for example, instead of portland cement. The recently-built Harvard Medical School Building (Figure 1) is an example. Wall panels are three inches thick, with facings one-inch thick glass fiber-reinforced-polyester concrete and core one inch of plastic foam. No lengthy cure is needed, panels can be made today, erected tomorrow. We don't have a fifty-year history of the material, a problem common to many of new materials, I shall come back to this.

In fibrous composites, a great deal is being done. We're taking a bit of a lead from the space industry here in a crude sort of way. I should like to use several examples.

The first is the United States building at the Brussels World's Fair in the 1950s. (Figure 2) It has a 300-foot diameter, cable-supported roof with translucent sandwich-type panels consisting of glass fiber-reinforced polyester on an aluminum grid; light in weight, tough, strong, and now being used quite widely for industrial, commercial, religious and school buildings: roofs and sidewalls.

The next example illustrates the use of glass-fiber-reinforced plastics in shell forms. One of the problems with these materials is their low

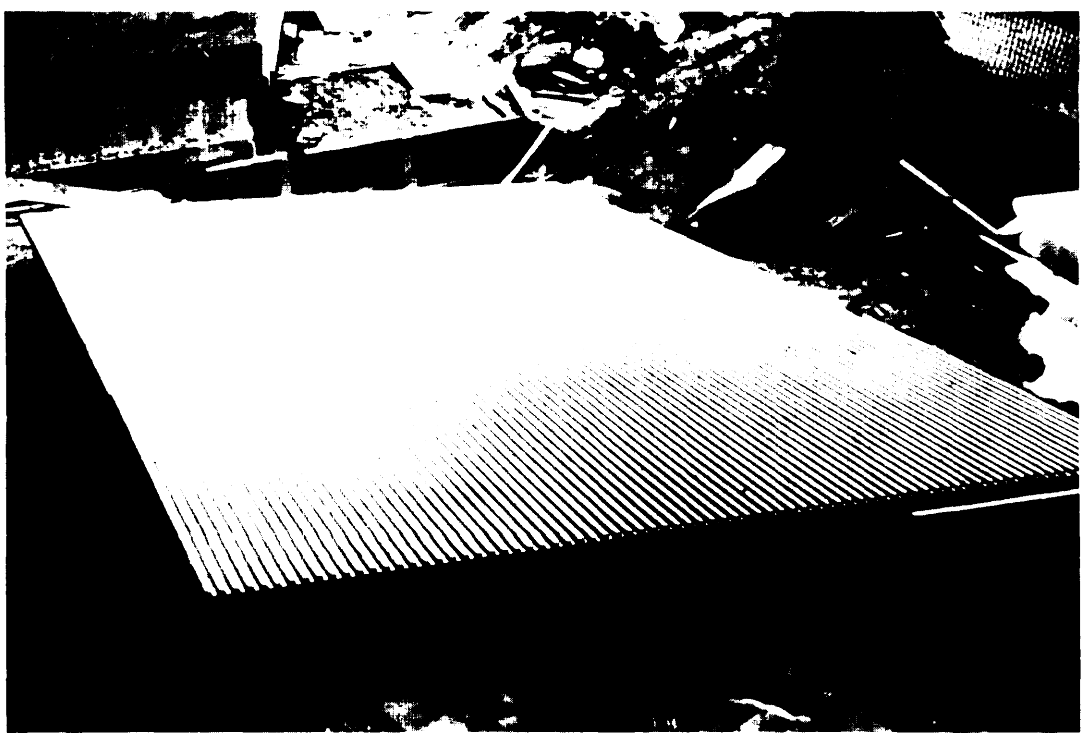

Figure 1

Sandwich wall panel with polyester-concrete facings and foamed-plastic cord elastic modulus. Consequently, they have low stiffness, and in order to make them work at all, curved inherently-stiff shapes must often be used.

Figure 3 shows the pavilions built for the United States exhibition in Moscow twenty-five years ago. They are 24 feet high, 16 feet across, with canopies one-sixteenth inch thick and quarter-inch thick ribs, the stiffness coming about more from the geometry than from the inherent properties of the material itself.

The next illustration, (Figure 4), is another shell form, the so-called House of the Future, built in Disneyland about thirty years ago. It is still the house of the future, but it was a pio neering use of the shell in the form of a monocoque. It was originally designed to be up for one year, was left up for ten and then posed a real challenge to the wreckers when the site was needed for something else.

Another composite application is a case history illustrating a number of interlocking factors that have to be taken into account simultaneously. About twenty years ago, the Greater London Council decided to use performance specifications for the exterior cladding of a projected series of twelve 25-story apartment buildings for moderate-income housing. The specifications said nothing about materials; but called for resistance to 80 mile per hour winds, a U factor of about 0.20, an acoustic attenuation factor of about 35, one-hour fire penetration resistance, essentially zero flame spread, minimum thickness, minimum weight, and about a thirty-year life without appreciable maintenance. No materials were specified.

Out of many conferences came a composite panel (Figure 5). The outer face was a press-molded skin of glass fiber-reinforced polyester loaded with mineral and turned out by a sports-car body manufacturer. The filling was foamed concrete, weighing about 20 pounds per cubic foot, reinforced with light wire. On the inside was gypsum plaster, reinforced with glass fiber and abestos, with a vapor seal and binder of bitumen between the gypsum and concrete. To allow for differential expansion and contraction, the outer shell was bonded to the concrete with expoxy adhesive and a thin layer of polyurethane foam.

Figure 2

Cable-supported translucent sandwich-panel roof of United States building, Brussels World's Fair.

Figure 3

Glass fiber-reinforced canopies and stalks, pavilions at United States Exhibition in Moscow

This was a composite of composites. It met all of the requirements of the British Fire Research Station. It weighed 15 percent as much as standard masonry or concrete construction. The in-place cost as estimated by the builder was more than competitive with the standard construction, because of speed and ease of erection.

Four buildings were built, and then the other eight were scrapped, not because of any technical problems. It was a technological success. It was a sociological failure. People refused to move into 25-story buildings. They just didn't want to live in them.

When only four buildings were built instead of twelve, the economics changed. Subsequently, five-story buildings were built, and standard masonry construction was just as competitive as the composite panel.

This case illustrates a number of things. Performance specifications made possible the marriage of a number of different materials to perform the overall requirements. The result was generally successful. Over the twenty years the panels have been up, they have behaved quite well. There have been some blemishes which had to be repaired in situ.

The repairs, though successful, show. The patches don't match the original material, and little spots appear on the surfaces.

The heavy aluminum windows were a failure and had to be replaced, with some damage to the panels, requiring repairs. A hot fire in one apartment broke through windows and scorched the outside surface, but did not spread (Figure 6).

The engineers are in favor of the system, but it has not been used again.

One problem was: who would produce these panels? There was no existing industry. The little engineering firm that undertook this job had to scramble around and find a panel molder in Ohio, various suppliers in the British Isles, and bring all of the elements together in one place, where the builder assembled them off site and erected them, using the same equipment as for the rest of the building.

This is a capsule illustrating some of the things that can be done with composites, and some of the problems that occur when we try to

Figure 4

Glass fiber-reinforced monocaque structural cantilevers, House of the Future, Disneyland.

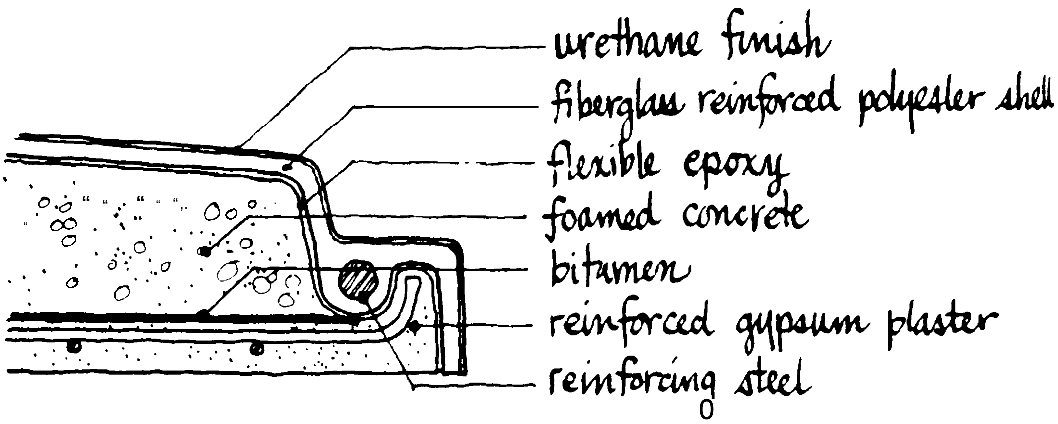

Figure 5

Composite wall panels. Greater London Council buildings.

Figure 6

Greater London Council building showing the outside structure.

introduce a fairly new material.

What are some of the probable future developments? What are some of the effects on the building industry? Plastics in general and the composites by and large lend themselves best to shop fabrication. They're not good when it comes to field fabrication, You can't take a hammer and saw and cut off some pieces and nail them together. The trend is toward more and more shop fabrication of finished components, and this is where plastics and composites fit in particularly well, right in line with the trend. New processes are involved, however, with which the building industry is not acquainted. Sometimes big presses are needed, sometimes materials and product handling are different. Builders will have to get used to them.

New building, forms are possible. The House of the Future, for example, looks entirely different from a standard house. The tension form for the Jedda Airport in Saudi Arabia (Figure 7), consisting of about 500,000 square feet of Teflon-coated glass fabric, is another example of a new type of form. It's a tent. At the Osaka Fair, the United States building — air-supported, vinyl-coated glass fabric — was another type of form made possible by the new materials (Figure 8).

Perhaps we can make contribution to energy conservation. The plastic foams are among the best insulators that we have from the standpoints of efficiency and use. There also can be problems with them as we found out with the formaldehyde.

Perhaps we shall have contributions from the Space Program. In any event, we shall find that our usual methods of fabricating parts for buildings will undergo changes as we bring in unfamiliar materials including plastics, other polymers and composite materials.

Now, what are some of the influences affecting use of unfamiliar materials? One major influence retarding the rapid adoption of these materials is uncertainty, particularly in two directions. The first is, how do they behave in fire? Many are organic materials. Any organic material can be destroyed by a hot enough fire. So how do we get around the problem of their susceptibility to fire? Of course, we use many

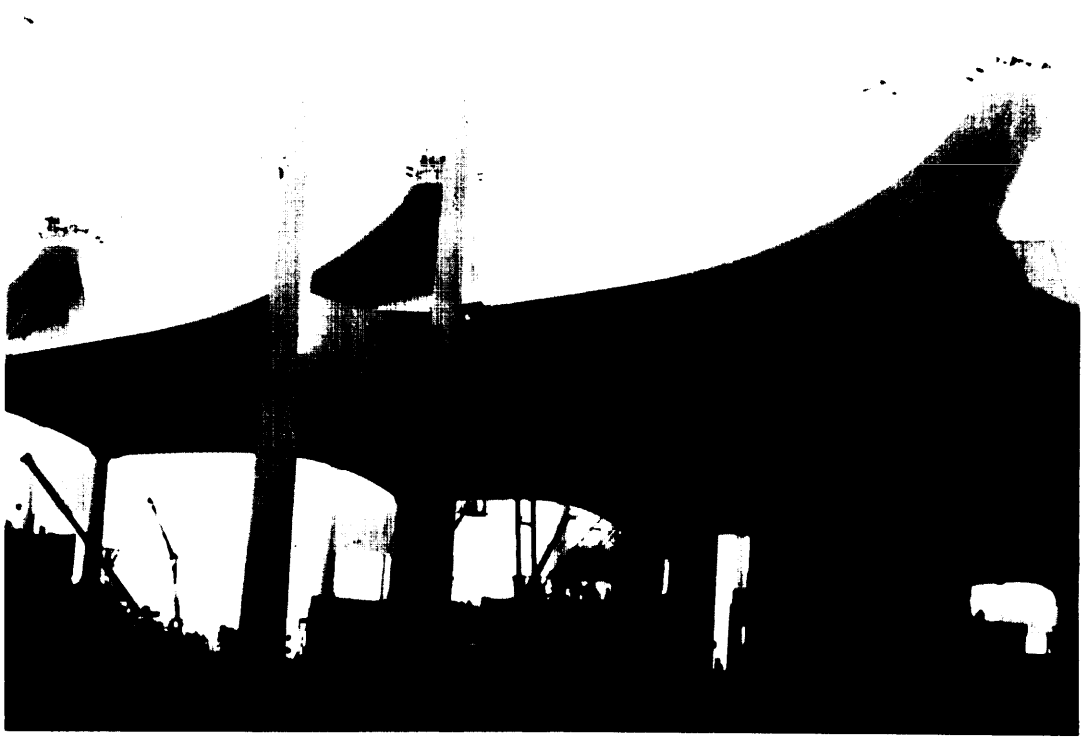

Figure 7

Tent roofs, 45 meters square, Teflon-coated glass fabric, Jeddah Airport.

materials in buildings that are susceptible to fire. That's not a new situation, but there are new aspects to it with respect to plastics, and the fire tests that we generally make may or may not be directly applicable to these new materials.

There's a great deal of work that needs to be done on fire evaluation generally, and not only for plastics and composites. This activity will have to be carried on somewhere.

The second question is long life, longevity. How will these materials stand up for a long period of time? Here we come to a question of definition. If you talk to the plastics people, "Oh, sure, these things will stand up for a long time."

"what do you mean?"

"Oh five or ten years." A building five years old is practically brand new, out of the box, and when you tell them, "No, we're not interested in that, but we want at least twenty-five, thirty years, preferably fifty years," the surprised reaction is likely to be, "Oh, no, we can't promise that." So there is the question. We do not have good ways of predicting long life, especially with new types of materials. This is another field in which a great deal of work needs to be done.

There are other things we could talk about: education, activities abroad, and many more.

There are several areas for concentration. I've already mentioned two. One is fire, and I mean fundamental work on fire, not just ASTM tests. These are very good tests and we have very good commercial establishments for running tests. We need fundamental research such as fire modeling and how to go from a small-scale test to prediction of actual behavior in large-scale fire. This kind of research is not the province of any one company. It will be up to Government agencies, such as the Bureau of Standards, which is doing good work, but is vulnerable to changes in government policy. Universities can contribute to such research. This type of work needs to be carried along and fully supported for an extended period.

Long-term prediction is another area. We do not yet know how to make a short-time test which will accurately predict how materials, especially new and familiar ones, will behave over

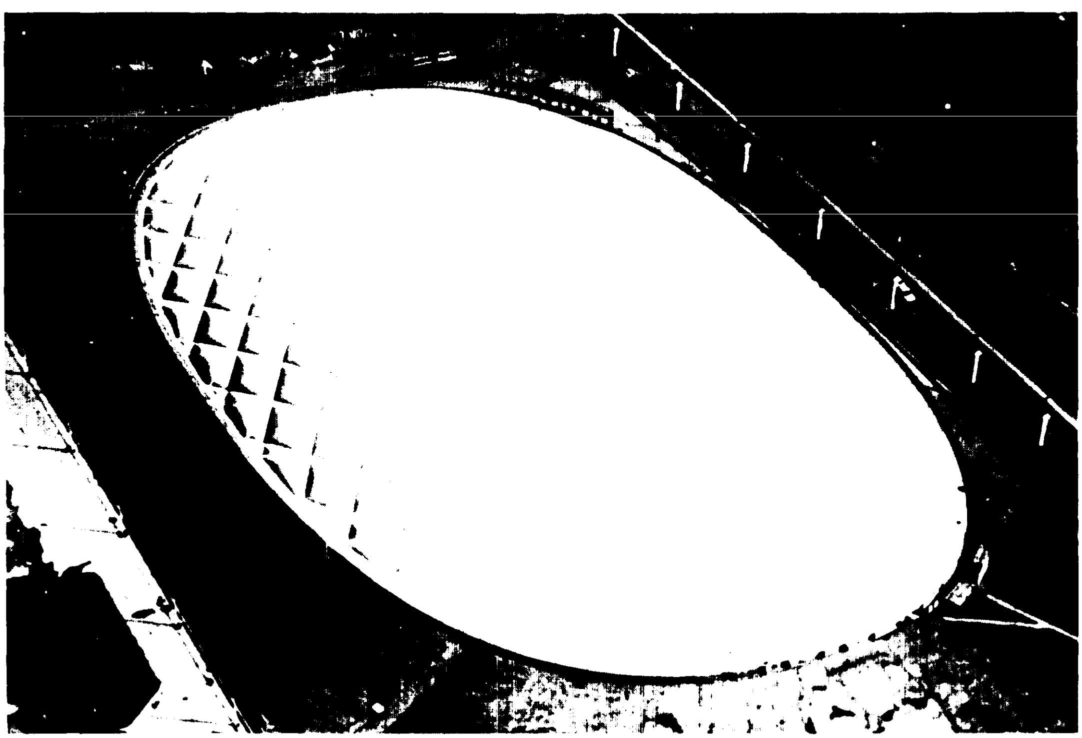

Figure 8

Air-supported vinyl-coated glass fabric roof, United States Building, Osaka Expo '70 Fair.

a long period of time. So we have our test racks facing south Florida and Maine and try to get some idea from them, but those results are both limited and slow.

Information dissemination; this has been raised before, and is a serious deficiency. Information just doesn't get around well in the building industry. There are thousands and thousands of small-scale builders, and it's hard to get the information around. It's very hard to get it together in the first place. It's there somewhere in somebody's file, but it's not getting around.

We don't know how our materials really behave in our buildings. These buildings constitute the biggest laboratory in the world, but we don't really make a systematic study of our materials in place, and therefore, we can't develop tests that will adequately predict their behavior.

The question of codes has been brought up earlier. They are important, no question about it. Codes can stand in the way of the use of new materials. The question of performance codes has been raised. A performance code calls for a needed upgrading of the abilities of our building inspectors. You can't have a performance code and just any political appointee going out looking at your buildings to determine if they comform to performance codes.

We ought to have systems of evaluations, such as are found in some of the European countries, which we don't have here. These things are among the aspects that we have to consider, and perhaps this panel should be thinking about them when looking into materials.

Albert Dietz is Professor Emeritus of the School of Architecture and Planning, of the Massachusetts Institute of Technology