Materials for a Prototype Human Habitable Bridge

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Submitted towards the fulfillment of the requirements for the Doctor of Architecture Degree

School of Architecture

University of Hawaiʻi

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We certify that we have reviewed this Doctorate Project and that, in our opinion, it is satisfactory in scope and quality in fulfillment as a Doctorate Project for the degree of Doctor of Architecture in the School of Architecture, University of Hawaiʻi at Manoa.

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Abstract:

A review is made of the general non-construction specifications for innovative as well as construction specification literature available for these materials. This innovation and utilization of advanced composite materials (ACM's), in the architectural and construction industry, allows for shapes and forms never before available.

These ACM's were originally (1930's and 40's) known as fiber reinforced polymers (FRP) and glass reinforced polymers (GRP)[1]. Their evolution into ACM's (1960's) has not yet gained total acceptance in the architecture and construction industry, although many forms of these materials are heavily used in the automotive, aerospace and sports industry. To begin we will look at how these material fibers are made, bonded together with various types of matrices and their structural characteristics for construction.

Through new research, ACM's durability, light weight and strength has created a new interest for architects and engineers. We will look at the "Thermo-plastic" and "Thermo-set" processes as well as the newly developed 3-D weaving process, allowing for the weaving of structural shape sections for use in construction.

An analysis of these components and their characteristics will illustrate their future potential for architects and engineers as a viable material for use as both a structural member and as an applied veneer for the exterior of a structure. And finally, we will address what the future might look like with these new materials.

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1. *Engineers Guide to Composite Materials,* 1987

Project Statement and Learning Outcome

As society occupies more and more land for its commercial, residential and recreational activities it reduces the land needed to stabilize the environment, maintain current weather patterns and also land needed for food production.

From the onset it appears that the scope of this project is never ending. For this reason a number of parameters must be placed to create an initial boundary around what is intended to be done for this particular paper. Hence, I will present the idea in full spectrum in the following project. Once the overall concept is placed in plain sight, I will narrow the focus to what is deemed to be the most value at this time. It can be simply said that technologies already exist that can provide the ideas presented. But that would be avoiding the presentation of the alternatives that are available. The main focus of this study is to review the use of *advanced composite* materials including the various *fiber reinforcement fabrics* for the actual construction of the project. These materials will be more clearly defined as we proceed through this study. For the most part an effort has been made to place a narrow definition to some of the terms used during the course of this paper. When the term is initially introduced it will be presented in *italicized* form and its meaning for our purpose set forth in the glossary located in the appendix.

This project has a number of objectives in its research. One of the major points is to determine if it is possible to provide alternative space and acreage for society to inhabit and conduct its business. Another point of interest to this objective is whether or not it is possible to provide these types of activities (housing, commercial and recreational spaces) above transportation patterns such as bridges which are constantly been constructed, renovated and upgraded for our growing cities. This idea is not a new one it has been around for centuries, and it has also been proven to be successful.

In conjunction with the revival of this old idea is the adaptation of a new concept, one for the needed materials to construct this bridge. The new materials in consideration are “Advanced

Composite Materials" (ACM) these are lighter and stronger than existing concrete and steel.

These materials are typically carbonized and graphitized filaments bonded together with various types of "Polymers" called "Matrix" [1] to create a lighter and stronger material for construction of all types of structures and shapes.

It is also important to determine if the recent spur of information on "Advanced Composites" (ACM) for construction is viable for conventional construction technique in architectural construction. Another question is to determine the availability of ACM construction materials and shapes, available for conventional construction techniques. Still another is the cost viability of these new materials.

A number of questions, which also need discussing are:

What kinds of materials are available for construction?

What are the available shapes for construction?

Are there exotic techniques which require new training?

How these new materials affect the design process for the Architect and the Engineers?

What are the spans and clearances available for using these new materials?

What are the advantages and disadvantages of these new materials over existing materials?

Are there new life safety issues to be concerned with?

What does this new materials do to the aesthetics of the structure?

How and when can these new materials be recycled?

Certainly there are many other questions, which can be stated needing answers regarding the use of these new materials, but for the moment a simple note to this will suffice, as new questions appear they will be answered within the text

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1. *Composite Basics*, Andrew C. Marshall, 1995

Part I: Introduction

Introduction

Let's begin at the beginning. I became interested in doing work in Vietnam when some acquaintances of mine asked if I would be interested in co-developing a housing project there. The economy in Hawaii was in somewhat of a slump, and due to my interest in affordable housing I thought it would be an interesting and challenging project.

The initial two week stay for due diligence was impressive. The people I spoke with in both the private and public sectors were very friendly, courteous and quite helpful. To me it showed a great potential for accomplishing some great architectural work. The people were becoming more consumers/ capitalistic oriented wanting a better lifestyle, in particular modeled after that of the United States.

After several months of living and working in Vietnam with various architects and government agencies a regular routine of meeting with a number of members of the Peoples Committee of District One for HoChiMinh City (equivalent to our city council in the US). Every Sunday we would meet for breakfast and I would assist them in learning English (American). Some two years of this allowed me to develop a relationship with everyone so that they were accepting of some critical comments that I would make. It was understood that the objective was always for the benefit of all to improve themselves. In October 1996 an article in the Saigon Times (an English written business magazine) was published regarding the outcome of a competition for a bridge to connect District One with District Two across the river which is to become the new government and business center. Both proposals offered to provide a draw bridge across a 400 meter (1,312 feet) long. I had made the comment that "to me this is not an acceptable solution for a country in the beginning of its new life". One of the more critical directors and sponsors of the competition immediately challenged my comment and asked for a better alternative. As is my nature (which on several occasions has caused me to ask myself "why did I say that?"). My reply was that "We are approaching the 21^{st} century and HoChiMinh City should not have to be satisfied with receiving a 15^{th} century solution. Both the city and the people deserve to have the latest and best technology has to offer, and so the search began for a better and more viable solution.

At this same time I was in the process of developing and building a decorative stone facility which allowed for increasing the production of stone panels by 100% using advanced composites to make the panels thinner, lighter and stronger and with the ability to repair portions of the panel without having to replace the entire piece. Having this in mind, I thought of the possibilities of using these new materials for this bridge project, and thus the research began.

The research in this study is concerned with the feasibility of providing a multi use structure. This structure can be used both as a bridge crossing for traversing a 400 meter (1,312 foot) wide river (the Saigon River in HoChiMinh City (HCMC) in Vietnam). In part, the bridge would provide new housing for the people who would be displaced by the development on the Eastern side of the river, and in addition, provide the required clearances for existing ships traffic to continue navigating through to the shipyard nearby and at an up-river destinations.

Because of the span and timeframe for construction, we will look at various types of new materials currently available to the industry. The products we will be most concerned with will be the Advanced Composites Materials (ACM's).

Since the beginning of time man has used a variety of materials to create and build shelters to protect him from the weather, wild beasts and other elements, to which Nature has exposed him. Man initially used the materials readily available to him in his surrounding environment. The first materials he learned to use were mud, wood, animal skins as well as stone. Surprising as it may seem, not much has changed. Man still uses these materials in one form or another.

Several millennia ago the Minoans and Babylonians were among the first to create a composite material. This material was made of mud and grass or straw, (whichever one prefers to believe) and dried in the sun to harden; this became the "mud brick" which became popular throughout the ancient world. These bricks were made to a standard size and small scale which was most adequate for the work at hand. The brick created a durable and most useful wall for its users.

Using tree limbs, grasses and straw [1], man was able to create a roof over these walls with openings (doors and or windows) to allow people, light and air access to the inside of the newly created spaces.

It was not until sometime later that the Romans developed a new composite material; this material was called concrete. This new composite made it possible to build bigger and better structures. This was also the first material, which could be designed for a specific use with specific characteristics. Over time man has continued to learn how to create and make better and stronger composites. Many such materials are still use today [2].

Man started constructing homes, temples and other structures using objects available to him. As man started using composites he crossed the road to making materials on a molecular scale. This is exemplified by the creation of very specific types of concrete, steel, aluminum and latter in the early 1900's … plastics.

In the mid to late twentieth century man started to develop materials on an atomic level. This endeavor is exemplified by the creation of "Advanced Composite Materials" (ACM's) these materials are typically made up of glass fibers with the stronger more sophisticated fibers known as carbon fiber, Kevlar©, Spectra ©fibers and many others.

The initial material to be used to research and application to the construction process was going to be *Carbon Nanotubes* however this presented a problem. In as much as these are the strongest material known to man, we have yet to learn how to bind them together to form specific shapes that can be used for construction. Carbon Nanotubes are as strong as diamonds (in fact that is what diamonds are made of), the trick is in shaping them to a useable form. It is theorized that a number of computerized "fabricators" can be programmed to build a structure of any size as one monolithic unit. This would be done by the constant addition of the base carbon materials needed for the Nanotubes. However, the next best materials are the advanced composites.

1. *Man the Builder,* Gosta E. Sandstom, 1970
2. *Fundamentals of Building Construction Materials & Methods*, Edward Allen, 1999

This doctorate project was intended to establish base parameters for a prototype alternative community and its infrastructure system for undeveloped, emerging and semi-industrialized; and perhaps fully industrialized countries in the new Millennium.

In most countries, both emerging and industrialized, cities and towns will for the most part develop along its major rivers. The navigability and transportability of goods along the river makes it ideal for these communities to develop there.

The concept was to develop a prototype multi-use structure that can accomplish several objectives for the governing body and its populace. This was to resolve housing and transportation problems within their jurisdiction, by rejuvenating an old idea and develop its component structures in a new way.

As housing was developed it created small villages along the riverfront, what we find is, in time this village will attract more and more people from both its land transportation route and its river system. As the village becomes large enough for commercial trade, new sections will be established on both sides of the river as well as inland; it will also develop additional commerce along overland routes near the expanding town.

Once this scenario begins to build on itself, a large community or "city" will develop. At this point the governing entity will begin to establish physical links or "bridge" the two sides of the river. Initially, this bridge is merely for transportation; however over the years, as was the case during the Renaissance, the creativity of entrepreneurs took advantage of the open space on the bridge to provide for business, as well as housing, which was usually above the business establishment.

Numerous residents occupied bridges as can be seen in Florence and Venice, Italy was a method of commercialization that proved to be very effective for occupying available space, which was not normally available to the merchant. This means of accommodation proved to be very successful. These bridges were successful enough to be adopted and built by many countries throughout Europe.

Some of these facilities are still in use today. However, as more land became available, the populace began to move into the newly afforded land-based housing. As business establishments developed, the cycle repeated itself. This now created additional problems for the government and it had to provide for transportation and circulation within the city. Not only did the government have to provide transportation routes on land, but also across rivers. The roads and streets developed of themselves in, somewhat of a haphazard fashion. However bridges, connecting the communities on both sides of the river was left for the government to build develop and maintain and then used by its citizens.

As a transportation system develops and a village grows into a town and later a city, housing becomes a prime concern. The government initiates more deforestation and land clearing to allow for additional housing. In many cases, the people are not able to provide their own housing and thus efforts are made to provide the minimally required standards for the poor and those who need shelter. Thus an enlightened society is now up to date in time and social values.

In providing solutions to transportation problems across rivers a government will build large elaborate bridge structures, to enable the crossing of the river. Any government should also exert a great deal of effort to provide housing for its people. While providing these facilities the government has to also provide the infrastructure for people to live and work. In order for this to occur, the land area around the small river town is cleared of trees and forest, thus destroying more of our valued environment.

One way to resolve some of these problems is to use the needed structure of a bridge and enhance it, (to a degree) by providing housing and commercial spaces within the new structure. In addressing these issues, policies need to be developed so as to begin the process of establishing community infrastructure, and the social fabric required for the success of this renewed way of living. It is my contention that a prototype of this nature can provide a foundation for a more environmentally sensitive and sustainable architectural building type. There have been in the past some whimsical attempts to view this type of structure for habitation as to what was, not what it can be.

It is understandable that many consider this a monumental task which can take years to comprehend and develop, however this discussion will be minimized by focusing on two or three main issues.

To begin with, I have to identify the issues that are important to such an endeavor. It is important to know what the government is willing to pay for the structure. Secondly, it is important to identify the issues of the people who will use this facility and address those. Thirdly, it is important to identify the issues the architect, engineer and the contractor/builder of the bridge need to know and be familiar with.

The first thought is how can such a mixed use facility be designed so as not to overwhelm the existing community? Then what type of materials should be used to provide this new structure? The conventional materials currently used are too bulky and heavy to make the structure economically sustainable. Materials in use today to build large structures use a great deal of raw material to support it, before it can support the functions it is to accommodate. A new way of thinking of construction method has to be developed. The new materials are here now; new methods are also here now. It is a matter of accepting, and further developing their potential. In other words we need a paradigm shift in how we build our structures.

Some of the questions to be answered are.

What type and shapes of ACM's are available for construction?

How does the material affect the design process?

Are there any advantages of these materials over the existing materials?

Certainly there are many other questions, which can be stated and show need for answers; regarding the use of these new materials, however for the moment simply noting these will be sufficient.

From the onset it appears that the scope of this project is never ending. For this reason a number of parameters must place to create an initial boundary around what I intend to do for this particular paper. Hence, I will present the idea in full spectrum. Once the overall concept is defined then narrowing the focus to what is deemed to be of most value at this time. It can be simply said that technologies already exist which can provide the idea. But, that would be avoiding the presentation of the alternatives in mind to be present. The main focus of this study is to view the use of *advanced composite* materials including the various *fiber reinforcement fabrics* for the actual construction of the project. These materials will be more clearly defined as we proceed through this doctorate project. For the most part an effort has been made to place a narrow definition on some of the terms used during the course of this paper. When a term is initially introduced it will be presented in *italicized* form and present its meaning for our purpose in the glossary located in the appendix.

The Project Intent

This doctorate project is intended to establish means for providing a prototype alternative housing and infrastructure system for undeveloped, emerging and semi-industrialized communities, and perhaps to fully industrialized countries in the new Millennium.

In most countries, both merging and industrialized, cities and towns, for the most part develop along its major rivers. The navigability and transportability of goods along the river makes it ideal for these communities to develop.

The concept is to develop a prototype multi-use structure that can accomplish several objectives for the governing body, and the populace. The objective is to resolve housing and transportation problems within their jurisdiction, by rejuvenating an old idea Figure No. 1 and developing it in a new way.

Figure No. 1 Ponte Vecchio, Venice, Italy
Webshots, www.webshots.com

The main focus of this study is to view a new design for this type of structure; and at the same time illustrate and present the use of new *advanced composite* materials including the various *fiber reinforcement fabrics* for the actual construction of the project. These materials will be more clearly defined as we proceed through this study. For the most part an effort has been made to place a narrow definition to some of the terms use during the course of this paper. When the term is initially introduced it will be presented in *italicized* form and present its meaning for our purpose in the glossary.

In providing solutions to transportation problems that cross rivers and gorges, a government will necessarily build large elaborate bridge structures, to span the crossing of that river or gorge. With this growth the government will also exert a great deal of effort to provide housing for their constituents. While providing these facilities the government has to also provide the infrastructure for people to live and work within that location. In order for this to occur the land area around the small river town is cleared of trees and forest around the developing area, thus destroying more of our valued resources and environment.

One way to resolve some of these problems is to use the needed bridge structure, and enhance it (to a degree) by providing housing and commercial spaces within the structure. This concept has been proven to be an effective process as shown during the Renaissance in Venice, Italy where some bridges crossing a number of the larger canals support both housing and retail spaces while allowing vehicular traffic to occur. This was so successfully accomplished that many other cities around Europe have adopted the idea during the Renaissance and are still in use today.

The prototype intended to be developed, will assess this innovation on a larger scale. The intention is to review the use of alternative materials and energy sources to power the prototype community and perhaps have enough capacity to supply energy to the surrounding neighborhood.

In addressing these issues, initial social policies need to be developed to begin the process of establishing community infrastructure, and the social fabric required for the success of this new community, though it is not the focus of this study.

Over the years, there have been some whimsical attempts to view this type of structure for habitation, however it never came to fruition even as a study due to lack of support and funding. Now that land costs as well as construction costs are rising at an ever increasing rate this concept becomes more palatable.

The final product for this project will be presented in a written format discussing the program and issues addressed; as well as in a graphic format to better illustrate the potential application of the project with its minimal impact on the environment.

Issues to be addressed and defined in scope:

Advanced Composite Materials	Energy
Housing	Energy Resources
Social Implications	Structure (Bridge)
Political Implications	Support Facilities
Economic Implications	Sustainability
Development Costs	Operational Costs

As business establishments developed, the cycle expanded and repeated itself. This now created additional problems for the government and it had to provide for transportation and circulation within the city. Not only did the government have to provide transportation routes on land, but also across rivers. The roads and streets developed of themselves in, somewhat of a haphazard fashion. However bridges, connecting the communities on both sides of the river was left for the government to build, develop, maintain, and left then to be used by its citizens.

This project has a number of objectives. The primary two are, first to see if the recent growth of information on *"Advanced Composites Materials" (ACM),* for construction is actually viable for conventional construction techniques. The second is to determine the availability of ACM construction materials and shapes for conventional construction means and methods.

Project Background

In order to have a clear understanding of what it is I am trying to do for my D. Arch project I thought writing would be the best way to have a clear goal or statement of objectives.
Since the start of my studying architecture, for one reason or another, bridges have been of great interest to me although I was never quite sure why. One big reason for this interest is that they are so utilitarian and so many people have an opportunity to see them and use them; much more so than people seeing or using any particular building. It was very rewarding and challenging to me when asked to design and draw an old fashion railroad covered bridge for the Boy Scout camp near the finger lake region of New York State back in 1972. The camp had a narrow gage utility train and a great deal of tracks donated to them, and needed a bridge built to cross over a small ravine on the property. In any event that is the earliest recollection I have of a bridge or of designing one. Bridges seem so majestic and powerful sitting there traversing whatever space it is that causes it to be there.

There are several reasons for choosing this particular site in down town HoChiMinh City (HCMC). The most important one in my mind is that the Peoples Committee of HCMC held a competition for a bridge to cross the Saigon River. This bridge was to be located off Huynh Hue Boulevard, and cross over to the newly designated government district across the river from District 1, usually referred to as “Saigon”. The proposals presented were of the traditional type, see Figure no 2 by the French and Figure no 3 by the British. Because of the shipyard upriver from the bridge, a drawbridge was proposed as the most likely type to build. Other than causing a great deal of delay for motorists whenever a ship was to be moved, I thought that considering our entering the 21^{st} Century (the bridge was proposed in early 1996) this was somewhat archaic.

Figure No 2 The French Proposal (Saigon Times 1996)

Figure No 3 The British Proposal (Saigon Times 1996)

This started me thinking as to how useful this type of structure can be; and because of my long time interest in the environmental awareness needed to develop appropriate structures I began to research what venue could be used to accomplish this type of project. I believe that a prototype of this type can provide a foundation for a more environmentally sensitive and sustainable architectural building type see Figure no 4.

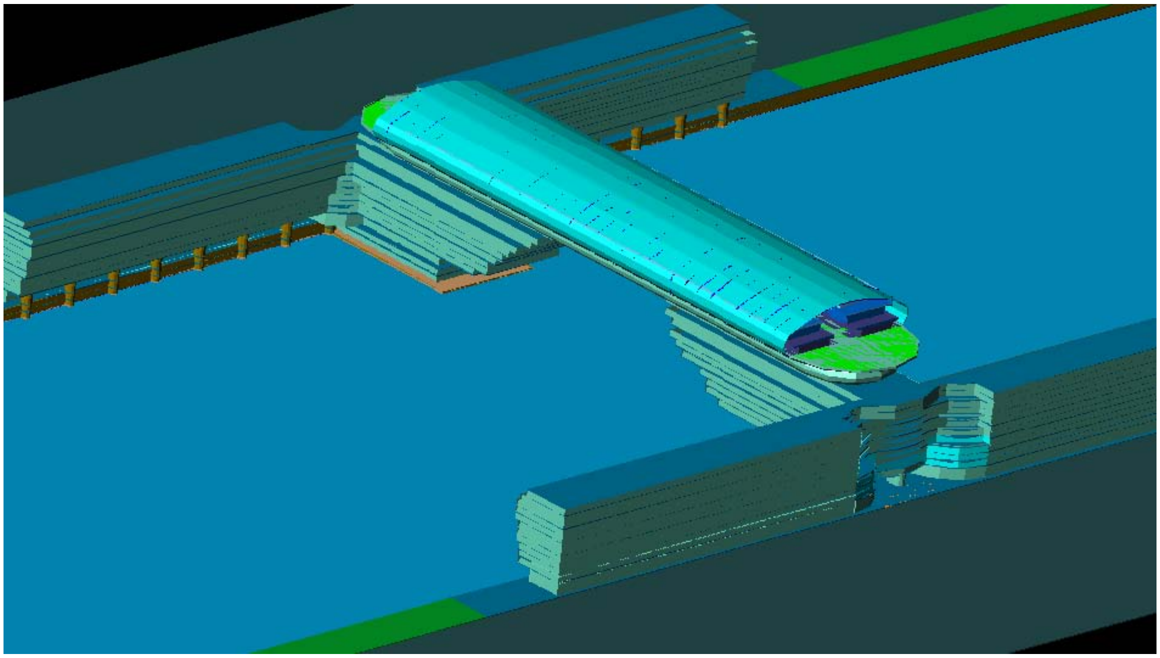


Figure No 4 Quantum Services proposal (Carlo Priska AIA 1998)

This affords us the opportunity to consider the community not only on the basis of the physical environment, but also the cultural and political aspects of that community. This new advanced planning technique can be used to reinforce traditional ways of living and architecture, which will influence the way the community, will continue to enhance its heritage and way of life. The final product for this project will be presented in both a written format, discussing the program and issues addressed as well, as in a graphic format; this to illustrate the potential application of the project with its reduced impact on the environment.

What follows are the beginnings of questions to be asked and addressed, along with the research format intend to be use as a skeletal outline of the approach to finding the answers to these very questions. Some of the research resources follow the proposed format.

Beginning with the most obvious issues first, not only to get them out of the way but also to continuously remind me of the reasons for designing this prototype structure.

1) The structure must span the Saigon River with little encroachment on the waterway.
2) It had to have a clearance for deep draft ships going to and from the shipyard up river.
3) Minimize the change in the sense of place or appearance to the neighborhood.
4) It has to accommodate the existing type vehicular traffic,

a. Cars	b. Trucks (to 4 metric ton)
c. Motorcycles	d. Powered Cycloe
e. Bicycles	f. Cycloe's
g. Pushcarts	h. Pedestrians
j. Roadside Vendors	

These activities are what make HCMC what it is. In the evening when the sun goes down the people, take advantage of the cool night's air to cruise around town to see and meet their friends and enjoy the sights.

A bridge could be much more than just a means of crossing over an obstacle. In Europe during the Renaissance people lived on bridges as well as providing a crossing. Large bridges along major thoroughfares had the gatekeepers live right on the bridge. This was a most effective way to provide housing for the care taker; since the structure is already their why not make it a bit stronger and provide housing? To follow along these lines a new series of activities are brought together.

5) Provide housing and its amenities,

a. Housing	b. Shops for groceries
c. Restaurants	d. Offices
e. Offsite parking	f. Emergency right of ways
g. Power collection system	h. Power distribution system
j. Water distribution system	k. Wastewater disposal system
m. Recreational spaces (park)	p. People circulation system
r. Communication system	s. Solid waste management

Now that some of the issues have been identified as major requirements of the structure, the next question that came up was; what do we build this out of so that it does not fall due to its massive weight?

The research began with a review of materials and systems available for the designer, started with the basics.

6) Some questions to ask and resolve.

a. What can a bridge do?

b. How does it do it?

c. What are the materials made of?

d. And finally, what can it be made of?

7) What are the materials available for this type of structure?

a. Concrete b. Steel

c. Cabling

d. Advanced composite materials

We know what concrete is, we know what steel is, and we know what cabling is. We also know that these in themselves are forms of composite materials, but the question is what are advanced composites? We know by the term that it is a combination of very specific types of materials combined together with various resins to create one material that can withstand the forces applied to it and still be lightweight.

Composite come in many forms and we will address them in a latter chapter. For our purpose the composites in consideration are as follows.

8) Composites to consider for the project

a. Glass b. Ceramic fibers

c. Carbon fibers d. Kevlar© fibers

e. Spectra© fiber f. Others?

All materials have some structural capabilities. Some have carrying capacity to only carry its own weight and need help to do anything more than that. Others have enough capacity to carry significantly more that its own weight. Once we start looking at these materials we start to ask about its aesthetic values. Is it visually pleasing enough for the material to be left exposed? And in doing so, is the material capable of withstanding the type of atmospheric conditions surrounding it without having to be protected by some other material?

The thought that comes to mind is to create a "Mega-Structure" which can accomplish all of this and perhaps find more functions that can be accommodated without sacrificing costs or load capacity of the structure.

As always the Question of cost comes to the surface. In our case the same question arises with the added caveat that the Vietnamese government does not have the financial wherewithal to finance such a project.

9) How do we resolve the issue of financing the construction of such a structure?

a. Borrow from the World Bank

b. Borrow from the Asia Development Bank

c. Borrow from a major financially strong country

10) How do we pay for this massive undertaking?

a. Sell environmental development rights

b. Sell physical development rights

c. Sell the available space on the bridge by the square meter

d. Charge a toll for crossing the bridge

e. Charge maintenance fees to the occupants of the bridge

The most important question to ask is "Can we build a community over airspace without damaging the environment so that it does not have to be remediated?"

The answer to this question is a resounding "YES!", and this is my attempt to prove this point.

Continuing along with the projects research, it was recommended that the scope of the project be narrower than what it presently is. At this point there was a decision to be made, and that is what is expected to be accomplished within the project?

To begin with we know that housing will work on a bridge or a suspension over an open area. We also know that traffic can be rearranged to approach a bridge with ample room for ascending to its appropriate height. We also know that providing additional spaces which could be used as offices, housing, retail, and other ancillary spaces within a structure would be no problem.

The focus therefore presented itself; it should be on providing or using advanced composite materials as structural elements for any type of construction project, including a bridge.

If the usability of these materials for construction can be shown, there would be no question in the use of advanced composite materials for a bridge, as a bridge is simply a high-rise structure lying on its side with supports at either end.

All of the same questions as indicated above would still need to be answered during the process of the research however to confine this paper to a narrow scope of work we shall introduce a design for such a structure and address the advanced composites for construction of structures only. During the course of the paper we shall address the materials used as composite fibers, the materials used to bond the composite fibers, and in part, the currying process.

Part II – The new Materials and Their Application

Advanced Composite Materials (ACM)

A. About ACM's

In discussing ACM's we must first establish a number of definitions for what composite materials actually are and at the same time we must define their major process characteristics in order to obtain a clear picture of these materials.

In general terms "composite" means, an assembly of dissimilar materials used together to enable them to perform certain type of work which individual materials cannot do by themselves alone. Under this definition, even reinforced concrete is a composite material.

For our purposes we will establish a working definition for advanced composites as that combination of materials that satisfy the following conditions.

1. It is manufactured (i.e. naturally occurring composites, such as wood, are excluded).
2. It consists of two or more physically and /or chemically distinct, suitably arranged or distributed phases with an interface separating them.
3. It has characteristics that are not depicted by any of the components (constituents) in isolation.

"*Advanced composites*" are composite materials that are traditionally used in the aerospace industries. These composites have high performance reinforcement of a thin diameter in a matrix material such as epoxy and aluminum. A composite material is a material made by combining materials which are different in form or composition on a macro-scale for the purpose of obtaining specific characteristics and properties. These constituents retain their identity such that they can be physically identified and exhibit an interface between one another, also these materials are carefully engineered and developed, and are uniquely suited to carry substantial load as structural members which are also significantly light weight. In contrast to typical composites such as reinforced concrete that is used in every day construction.

The possible material combinations in advanced composites are virtually unlimited. The constituent forms in advanced composites are more restricted. Major constituent forms used in composite materials are fibers, particles, lamina, flakes, fillers, and matrixes. These structural materials consist of two or more constituents which are combined at a macroscopic level and are not soluble in each other. One constituent is called the reinforcing phase (fibers) and the one in which it is embedded is called a matrix (epoxy). The reinforcing phase material may be in the form of fibers, particles, or flakes. The matrix is the binder which holds these fibers or particles together and provides an even load distribution to the reinforcing materials. These materials are either "organic" or "inorganic" compounds. The forerunners of these materials were, or in many cases, are still called, "Fiber Reinforced Polymers" (FRP) or "Glass Reinforced Plastic" (GRP).

Advanced composite are engineered components designed to fulfill very specific needs as presented by a user. These users traverse all industries, trades uses, and applications.

The development of ACM's did not come into its own until the late 20th century.[1]

The materials are made up of engineered fibers and resins or a "matrix" which is then combined with one of a combination of the many fibers available to the engineer.

Advanced Composite fibers are developed in a variety of forms, the most common forms been, chopped strands or "mat" (usually made up of cut fibers from 0.125" [3.2mm] to 2" [50.8 mm] in length) fig. 5a, strands (are very long fibers usually cut to the length requested by the user) fig.5b, woven fabric such as fig. 5c, and tapes such as fig. 5d. Each of the fiber to be used has a specified characteristic that is required for its particular use.

Fig.5a *Fig.5b*

Figure No.5 *Biteam Composites*

1. *Advanced Composite Materials*, Swanson 1997

Figure No.6 *Fig.5c Fig.5d*
(mat, strand, fabric & tapes) Biteam Composites

About the Process:

"Aramid fiber" is a generic name for a class of synthetic organic fibers called "aromatic polyamide" fibers. These are manufactured fiber in which the fiber forming substance is a long chain synthetic polyamide in which at least 85% of the amide linkages are attached directly to aromatic ring compounds based on the structure of benzene as opposed to linear compounds used to make nylon, which is a generic name for any long chain polyamide fig. 6, thermo-plastic fig.7a, and thermo-setting fig. 7b. This will be discussed further in Part III-A Structures.

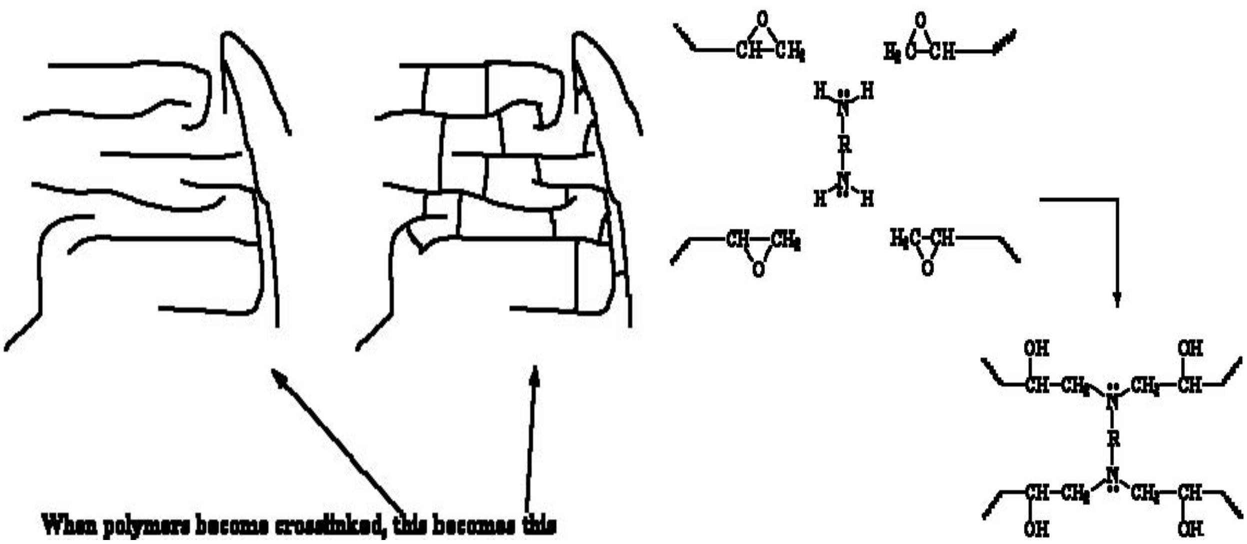


Figure No.7 *(linked and cross-linked molecules) http://fozzie.chem.wisc.edu Oct. 2006*

"Thermo-plastic" this is primarily a process by which the composite is capable of being repeatedly softened by increase of temperature and hardened by a decrease in temperature; this process is applicable to those materials that change upon heating which is substantially physical rather than chemical, and can be shaped by liquid flow into articles, by using a molding or an extrusion process. Many natural resins may be described as thermoplastic. With this type of resins, a product can be produced in a particular form, and, if that form is not configured to the specifications required by the client, it can be reprocessed to maintain the higher quality standard. This provides a reduction in cost due to disposal of an unacceptable shape or quality of product. This process also allows for recycling of materials which are not used or discarded.

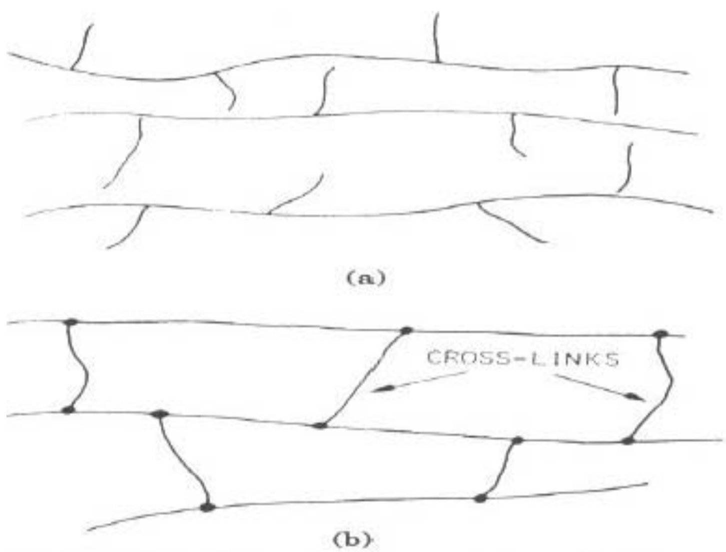


Figure No.8 *Schematic representation of (a) thermoplastic, (b) thermosetting polymers*
Mel Schwartz, Composite Materials Handbook

"Thermo-set" is also a primary process, considerably different from that of thermoplastic. The major difference is in that this is primarily a chemical reaction process. The plastic changes into a substantially infusible and insoluble material when it is cured by application of heat or by chemical means. With this particular technique, the advanced composites cannot be reshaped or remanufactured to satisfy a particular set of specifications. In this case, if the product does not meet the required quality, shape or form; it will have to be disposed of, as it is not usable in any other form.

Thermo-set materials usually consist of a resin matrix-typically an epoxy, polycyanate, polyester, or vinyl ester-and fiber reinforcement. The fiber reinforcement can be Glass fiber, Kevlar©, carbon fiber, Nextel©, quartz, boron, or any of a number of other fibers all of which are very small in diameter and very strong, imparting a high degree of strength to the resulting mixture. This added strength is so large that the performance of a composite as a structure is usually in another order of magnitude when compared to the strength of the resins by themselves. Even so, the strength and stiffness of the resin matrix does affect the finished composite structure; and stronger resins, such as epoxy, usually yield a higher strength structure than one which employs a lower strength resin, such as general-purpose polyester.

A-1.1 Classes of Composites

Composites are classified according to their matrix phase. There are polymer matrix composites (PMC's), ceramic matrix composites (CMC's), and metal matrix composites (MMC's). Materials within these composites are often called "advanced" if they combine the properties of high strength and high stiffness, low weight, corrosion resistance, and in some cases special electrical properties. In addition, these major classifications of composites are within themselves further classified by the arrangement of their constituents.

Constituents (an essential component or element) making up a composite can be arranged in two basic ways. The most common arrangement is in a regular and repetitive pattern, with a cross section that is relatively uniform in both material structure and density. These types of constituents are considered to be homogeneous. A second type is a variable pattern of constituents; these have no set arrangement or repetitive pattern in either internal form or materials. These materials are termed as graded or gradient composites. Laminated materials made up of several different layers are in this category. The structural constituents of both homogeneous and gradient composites can be arranged in either an oriented or random fashion. Using this explanation of the nature and structure of composites a working sub-classification of composites can be devised. Several sub-classification systems have been used in the composite manufacturing industry, one such sub-classification is by basic material combinations used, as follows:

1. Basic material combination e.g., metal-organic or metal-inorganic;
2. Bulk form characteristics e.g., matrix systems or laminates;
3. Distribution of the constituents e.g., continuous or discontinuous;
4. Material by function e.g., electrical or structural.

The sub-classification system we will use in this report is based on the structural constituents. There are five general sub-classes of composites that form this sub-class they are as follows:

1. Fiber composites composed of fibers with or without a matrix.
2. Flake composites composed of flat flakes with or without a matrix.
3. Particulate composites composed of particles with or without a matrix.
4. Filled (or skeletal) composites composed of a continuous skeletal matrix filled by a second material.
5. Laminar composites composed of layer or laminar constituents

The nature and morphology of composites is evident in that the behavior and properties of composites are determined by: the materials on which the composites are composed of; the form in structural arrangement of the constituents; and the interaction between the constituents, fig 9.

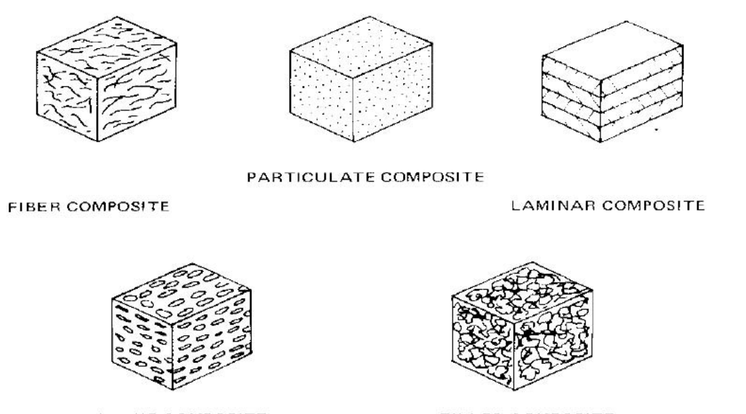


Figure No.9 *Classes of Composites (Composite Materials Handbook, Mel Schwartz)*

A-1.2 The makeup of ACM'S.

With the various types of fibers available in the industry, come a variety of matrices used to bind these fibers together. The "binder" most commonly referred to as a "polymer matrix" is a thermoset resin with polyester, vinyl ester and epoxy resins. Plastics such as polyethylene, acrylic, nylon, and polystyrene are more commonly known "thermoplastics". These can be heated to form a specified shape and then reheated to change or modify that shape. Typically a composite will use a "thermoset" resin which
begins as a liquid and turns into a solid during the curing or molding process due to heat and pressure applied to it, these cannot be melted or reshaped. Specialized resins such as Phenolic polyurethane and silicone are used for specific applications.

Most people know of composites due to "fiberglass" as a material for boats, cars, and a myriad of other consumer products. They are currently aware of "carbon fiber" products because of their use in athletic sporting goods such as golf clubs, tennis rackets and fishing poles. The architect's awareness of advanced composites in architectural construction is not yet apparent; however, these materials are starting to make themselves well known in the construction industry.
Each composite has to fulfill certain basic requirements. Composite shapes need to be light weight, high strength, corrosion resistant, durable and have design flexibility for product profile and production techniques. ACM's are broadly known as reinforced plastics but are designated by the industry as "Glass Fiber", "Carbon Fiber", "Aramids", and "Ceramics". Each of these groups has sub-groups to allow for very specific functions. Fiber glass for example is made up of a number of elements in a very precise amount, see fig.5 Composition.

A-1.3 Types of ACM's

A-1.3a - Glass and Glass Fibers:

Glass itself has been available to man for quite some time, however glass fibers have only been with us for less than one hundred years. Glass fiber is manufactured in a variety of molecular or atomic (chemical) compositions. Each type of fiber has its own specific characteristics and is designated as such by the different letter designations. The most commonly made glass fibers are designated as S-Glass, C-Glass, and E-Glass fig. 10. Of these three, the most common fibers E-Glass are most widely used. S-Glass is primarily used for aircraft and aviation applications, while C-Glass is primarily used in structures needing protection from a corrosive environment

Properties of Bare Single Filaments of some Advanced Fibers				
Properties				**Glass Type**
		E	**C**	**S**
Physical		(Electrical)	(Chemical)	(High Strength)
Specific Gravity		2.54	2.49	2.48
Moh Hardness		6.5	6.5	6.5
Contact Angle w/Water		0		
Coefficient of Friction w/Glass		1.0		
Moisture Absorbency (Surface) % up to		0.3		
Moisture Regain		none		
Mechanical				
Tensile Strength, psi	@ 75 ^{o}F.	500,000	480,000	665, 000
	@ 700 ^{o}F	380,000		645,000
	@ 1000 ^{o}F.	250,000		350,000
Tensile Modulus of Elasticity, psi @ 72 ^{o}F.		10.5x10^{6}	10.0x10^{6}	12.4x10^{6}
Hysteresis		none	none	None
Creep		none	none	None
Elongation at Break, %		4.8	4.8	5.7
Elastic Recovery, %		100%	100%	100%
Composition				
Silicone Oxide		55.2	65.0	65.0
Aluminum Oxide		8.0	4.0	25.0
Ferrous Oxide		-	-	0.21
Calcium Oxide		18.7	14.0	-
Magnesium Oxide		4.6	3.0	10.0

	Sodium Oxide		0.3	8.5	0.3
	Potassium Oxide		0.2	-	-
	Boron Oxide		7.3	5.0	-

Figure No.10 *Andrew C. Marshal, Composite Basics-5*

A-1.3 b - Carbon Fibers:

Carbon fiber products have become quite common and familiar to everyone. By the end of the twentieth century carbon fiber was being used for all type of athletic equipment needing to have high strength with very little weight. The most common items been produced are golf clubs, tennis rackets, bicycle frames as well as many automotive and aerospace components needing to be very light and very strong. Many products needing to meet these criteria of having to endure a great deal of stress and high temperature came to fall within the purview of carbon fiber products.

There are two primary types of carbon fiber processes. The first is PITCH based; this is made from pitch or coal tar, it is referred to as Pitch fibers and has a lower mechanical property and is rarely used in critical structural applications. Theoretically Pitch based carbon fibers are used because they provide a much lower cost to manufacture than PAN (polyacrylonitrile) fibers, however this has not yet to be proven in its actual production. Currently all carbon fiber fabric requires a surface oxidation treatment in order for the fabric to be more conducive to bonding with a matrix resin.

The second Carbon fiber type is PAN. The raw material of PAN is acrylonitrile (AN) a product of the chemical industry (similar to rayon). Acrylonitrile is used as a raw material in acrylic fibers, ABS resin, AS resin, synthetic rubber (NBR), as well as acrylamide and other products. Originally PAN was manufactured from acetylene and hydrogen cyanide (HCN) fig. 11. The process was epoch-making at its onset, Standard Oil Co. of Ohio (Sohio) created a gas reaction not only containing AN, but also acetonitrile, hydrogen cyanide and other gaseous based products.

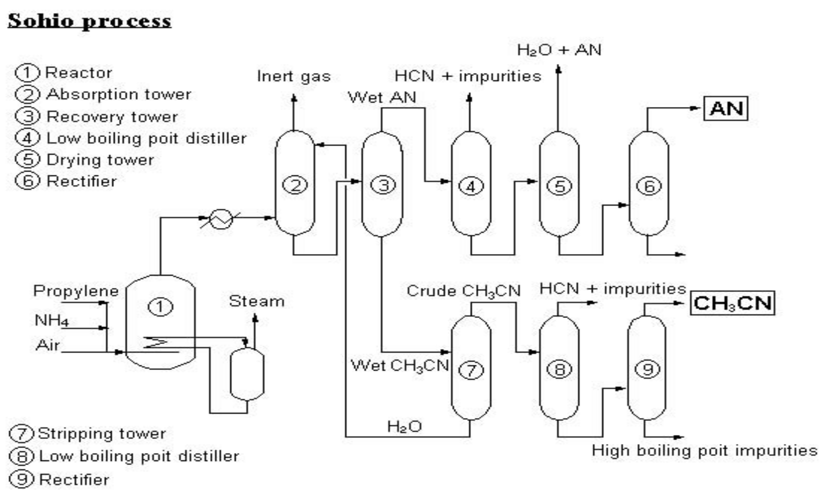


Figure No. 11 http://geocities.com/CapeCanaveral

Carbon fiber is made much like glass fiber; however it has to undergo three additional modifications in order to obtain its characteristics. The fiber roving has to initially go through an oxidation process (heated to 1292 ^{o}F / 700 ^{o}C) where it then proceeds through a carbonizing process (heated to 2552 to 3092 ^{o}F / 1400 to 1700 ^{o}C) and finally through a graphitizing process (3992 ^{o}F / 2200 ^{o}C). These are all three separate but a continuous process necessary to achieve the required characteristics of carbon fibers fig. 12.

	Grades of Carbon Fibers			(1GPa = 145,000psi)
Carbonization Temp. (C)	**to 1000**	**1000 to 1500**	**1500 to 2000**	**2000+ (Graphitization)**
Grade of Carbon Fiber	Low Modulus	Standard Modulus	Intermediate Modulus	High Modulus
Modulus of Elasticity (GPa)	to 200	200 to 250	250 to 325	325+

Figure No. 12 *Biteam Composites*

This process is typically performed on a multi strand roving of PAN fiber. This roving is provided in a form much like yarn is provided to weavers for weaving synthetic fabrics.

There is a significant difference between PAN and Pitch carbon fibers. PAN fiber is most often preferred due to its higher tensile strength and higher compressive strength fig. 13. For example, the PAN fiber T-1000, been offered by TORAY has a tensile strength approaching one million P.S.I. as well as many other fibers, not quite to this power but higher than 550 to 600 K.S.I. of most PAN fibers.

Carbon Fiber	**(1GPa = 145,000 psi)**		
Strength Characteristics		**Tensile Strength (GPa)**	**Tensile Modulus (GPa)**
High Tenacity		4.00	240
Ultra High Tenacity		4.80	240
Intermediate Modulus		6.00	290
High Modulus		3.50	375
Ultra High Modulus		3.40	425
High Modulus/Tenacity		3.90	400

Figure No. 13 *Biteam Composites*

A-1.3 c - Kevlar© Fibers:

Kevlar is most often used as an example in describing the Aramid fibers but most people Kevlar is better known for its use in bullet proof vests used by most police forces, the Kevlar© helmets used by the military as well as their vehicle and personnel armor. These are all of the Kevlar© #29 series, which was an early version of Kevlar©. The newer Kevlar© #49 and #149 series can be used for construction purposes. These have the same strength as Kevlar© #29 but differs considerable in that they have a higher modulus.

In addition to this, these latter versions do not conduct electricity as carbon fiber does. Also Kevlar© #49 and #149 are not opaque to radio waves. Kevlar© acts much like glass fibers as it relates to construction.

Kevlar© fiber is another new material used in producing advanced composite products. Kevlar© has many of the same attributes as glass fibers and carbon fibers fig. 14. However it has one characteristic which places it in front of the others and that is its toughness. This is unique to Kevlar. By combining Kevlar© with other advanced composite fabrics the combined cloth provides the superior characteristic of each fabric and virtually eliminating the flaws in each of the fabrics used for the product.

Comparison of relative properties of reinforced fabrics			
P= Poor	F= Fair	G= Good	E= Excellent
	Glass Fibers	**Carbon Fibers**	**Kevlar Fibers**
Density	P	E	E
Tensile Strength	F	E	G
Compressive Strength	G	E	P
Stiffness	F	F	G
Fatigue Resistance	G-E	G	E
Abrasion Resistance	F	F	E
Sanding/Machining	E	E	P
Conductivity	P	E	P
Heat Resistance	E	E	F
Moisture Resistance	G	G	F
Resin Compatibility	E	E	F
Cost	E	P	F

Figure No. 14 *Stephen R. Swanson, Advanced Composite Materials*

A-1.3 d - Other Advanced Composites:

There are many other advanced composite fabrics in the Aramid category for high strength, high stiffness aromatic polyamide fiber. There are many material fibers available in this category to be used in the construction industry. One very promising fiber – Nextel© Fibers presents a very interesting characteristic for the construction industry that its strength is a little less than glass fiber but its remarkable attribute is that its retention of properties at temperatures is in the range of 2000^{o}F. it becomes a prime material for use in fire walls and fire resistant structures.

Another new material Spectra© Fiber has its own unique characteristics. Its bonding capabilities are somewhat limited, and a difficult material to bond together with other materials, but it is the only fiber material with a specific gravity low enough to allow it to float on water. And still another material, which is most effective in temperature control, is Ceramic Fibers. These open an entirely new aspect in temperature and fire control.

This is the same material used to provide heat resistance to the space shuttle during its re-entry stage. Vectran© is a high-performance thermoplastic multifilament yarn spun from Vectra liquid crystal polymer (LCP). As liquid crystal aromatic polyester it is noted for its thermal and chemical stability, moisture resistance and high strength and modulus to enhance the performance of many other fabrics. Due to its excellent flex/fold characteristics the material is used in the reinforcement industry in hoses and diaphragm construction. This product shows great advantages for architectural use in fabric structures due to its high strength and modulus, excellent resistance to creep, high abrasion resistance, high impact resistance, minimal moisture absorption, high dielectric strength, outstanding cut resistance, and vibration damping characteristics.

A-2 Similarities and Differences in ACM's

The interesting characteristic of all these ACM materials is the retention of each composites own strong qualities while at the same time taking on the strength and flexural advantage of the accompanying material bonded to it; providing the desired quality and strength character the designers are attempting to achieve by combining the various types of fabrics, matrices and other added filler materials.

In comparing these materials with one another one can readily see the advantage and disadvantage of the material and their potential use in a variety of conditions fig.15.

Fiber Type Comparisons				
F - Fair		G - Good	E - Excellent	
Property		**Aramid**	**Carbon**	**Glass**
High Tensile Strength		G	E	G
High Tensile Modulus		G	E	F
High Compressive Strength		F	E	G
High Compressive Modulus		G	E	F
High Flexural Strength		F	E	G
High Flexural Modulus		G	E	F
High Impact Strength		E	F	G
High Inter-laminar Shear Strength	G	E	E	
High in-plane Shear Strength		G	E	E
Low Density		F	G	F
High Fatigue Resistance		G	E	F
High Fire Resistance		E	F	E
High Thermal Insulation		E	F	G
High Electrical Insulation		G	F	E
Low Thermal Expansion		E	E	E
Low Cost		F	F	E

Figure No. 15 *Stephen R. Swanson, Advanced Composite Materials*

ACM's are very much alike, but they are also very different in many ways. The likeness basically stops on the superficial level, by this I mean that they are all made in filament form, usually in the micro-meter dimension fig. 16.

All ACM fibers are woven into yarns for use, and they are bonded together with other fabrics and a precise matrix. The major aspect of ACM's is the way they are made and how they are prepared for bonding. With the exception of glass fibers most of the fibers go through a high temperature (1000^{0}F to 2500^{0}F) refinement. Carbon fibers for example go through the initial heating phase for formulation. This will begin the extrusion process for the fiber. The next phase of the makeup of the fiber is to begin the enhancement aspect which is to graphitize it to achieve the initial strength requirement. Once this is accomplished it is heated to above 2200 ^{0}F to achieve its maximum strength.

		Mechanical Properties of Typical Fibers					
		Fiber Density		Tensile Strength		Tensile Modulus	
Fiber	**Diameter (um)**	**lb/in ^{3}**	**(g/cc)**	**(ksi)**	**(GPa)**	**(Msi)**	**(Gpa)**
E-Glass	8 to 14	0.092	2.54	500.0	3.45	10.5	72.4
S-Glass	8 to 14	0.090	2.49	665.0	4.58	12.5	86.2
Polyethylene	10 to 12	0.035	0.97	392.0	2.70	12.6	87.0
Aramid (Kevlar 49)	12	0.052	1.44	525.0	3.62	19.0	130.0
HS Carbon, T-300	7	0.063	1.76	514.0	3.53	33.6	230.0
AS4 Carbon	7	0.065	1.80	580.0	4.00	33.0	228.0
IM7 Carbon	5	0.065	1.80	785.0	5.41	40.0	276.0
XUHM Carbon	-	0.068	1.88	550.0	3.79	62.0	428.0
GY80 Carbon	8.4	0.071	1.96	270.0	1.86	83.0	572.0
Panex 33 Carbon	-	0.064	1.78	525.0	3.60	33.0	228.0
Boron	50 to 203	0.094	2.60	500.0	3.44	59.0	407.0
Silicon Carbide	-	0.115	3.19	220.0	1.52	70.0	483.0

Figure No. 16 *Stephen R. Swanson, Advanced Composite Materials*

Many of the fibers have to be cleaned and sized (coated with a specific chemical cleaning and bonding agent) so that they do not separate or delaminate from the final bonding agent or have an adverse reaction with the material it is bonded to. As each of these fibers have its own unique chemical characteristic they also require their own varied treatment for the additional fiber they are to be combined with. Some fibers require a separation layer (non structural/neutral) to properly bond for the required strength and function it is to perform.

A-2.a Fiber factors

There are several factors which determine the engineering performance of a fiber matrix composite; among the most important are the orientation, length, shape, and composition of the fibers to mechanical properties of the matrix; this includes the integrity of the bond between the fibers and the matrix. Of all of these orientation of the fibers is perhaps the most important.

A-2.a.1 Orientation. Fiber orientation determines the mechanical strength of the composite and the direction in which that strength will be the greatest. There are three types of fiber orientation: one-dimensional reinforcement, (planar) two-dimensional reinforcement, and three-dimensional reinforcement. The one-dimensional type has maximum composite strength in modulus in the direction of fiber axes. The planar type exhibits different strains in each direction of fiber orientation. The three-dimensional type is isotropic but has greatly decreased reinforcing values. In this three-dimensional orientation approximately one third of its strength is in effect. The mechanical properties in any one direction are proportional to the amount of fiber by volume oriented in that direction. As fiber orientation becomes more random, the mechanical properties in any single direction become lower.

A-2.a.2 Length. Orientation of fibers in the matrix can be accomplished with either continuous or short fibers. Continuous fibers are more efficiently oriented than short fibers but they are not necessarily better. Theoretically continuous fibers can transmit an applied load or stress from the point of application to the reaction by a continuous load path.

Composites made from shorter fibers, if they could be properly oriented, could have substantially greater strains than those made from continuous fibers. This is particularly true of whiskers (another name for mat fibers), which have uniformed tensile strength as high as 1500 kips/in^2 (10.3 GPa). The reasoning for this is that short fibers can be produced with few surface flaws; they come extremely close to achieving their theoretical strength. In general continuous fibers are easier to handle but more limited in design possibility than short fibers.

A-2.a.3 **<u>Shape.</u>** Almost all fibers being presently used are circular in cross-section whether they are continuous or short; however, hexagonal, rectangular, polygonal, annular (hollow circle), and a regular cross-sections appear to promise improved mechanical properties. Solid rectangular cross section fibers (0.0004”/ 0.01mm) make it possible to obtain almost perfect packing. However the need for space between fibers for the matrix to bond to is still critical, more will be discussed under “structures”.

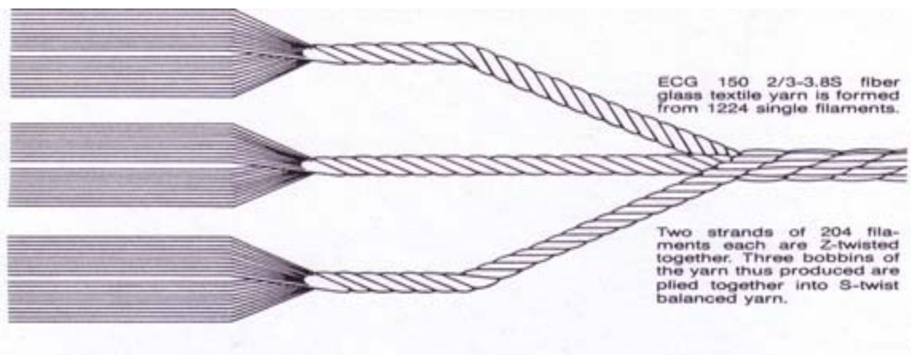
A-2.a.4 **<u>Composition.</u>** Fibers are available in organic and inorganic materials composition. The organics, such as cellulose, polypropylene, and graphite fibers, can be characterized in general as lightweight, flexible, elastic, and heat sensitive. Inorganic fibers, such as glass, tungsten, and ceramic, can be generally described as very high in strength, heat resistance, rigid, and low in energy absorption and fatigue resistance.

Many of the organic fibers satisfied both the strength and elasticity requirements for structural composites; graphite in recent years has become the most popular. The inorganics, notably glass, dominate the field of composites at this time; however other inorganic fibers, e.g., metallic whiskers and ceramic fibers, have recently shown much promise for cost efficiency and use.

B. ACM Materials.

B-1 <u>Threads the basic element;</u>

Advanced Composite fibers are most commonly produces as a yarn or roving. The properties of this roving are dependent on the strength, orientation and construction (as mentioned in section II A-2.a to A-2.a4) of the material for which it is made from. The usual make-up of a roving consists of any number of filaments, (usually 13,000 noted as 13k to 56,000 noted as 56k for a carbon fiber thread) one fiber filament is usually about 5 micro-meters thick twisted into a single larger thread (fig. 17), which then twisted with other threads to form a yarn, with this new larger "yarn" it is twisted together with two or more yarns to form one structural roving which are considered one fiber filament. These filaments are rolled into large spools to be use in weaving; cross-matched with other composite filaments weaving specific types of fabrics is then possible. These spools are also what provide the various filaments needed for different type of wound components such as fuel storage tanks or rocket exhaust nozzles and motors used in the U.S. space program.



Filament Designation	Nominal Filament Dia. (in.)	Strand Count (X100=yds/lb.)	Approx No. Filaments in Strand
D	0.00021	1800	51
B	0.00015	900	204
D	0.00021	900	102
B	0.00015	450	408
D	0.00021	450	204
DE	0.00025	300	204
D	0.00021	225	408
E	0.00029	225	204
B	0.00015	150	1224
C	0.00018	150	816
DE	0.00025	150	408
G	0.00036	150	204
H	0.00043	110	204
C	0.00018	75	1632
DE	0.00025	75	816
G	0.00036	75	408
K	0.00051	75	204
H	0.00043	55	408
DE	0.00025	37	1632
G	0.00036	37	816
K	0.00051	37	408
H	0.00043	25	816
K	0.00051	18	816
G	0.00036	15	2052

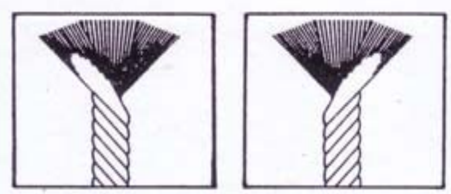
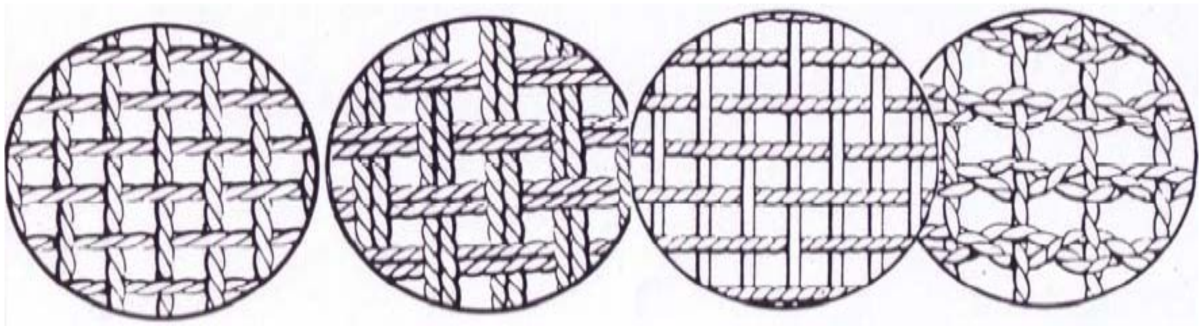


Figure No. 17 Andrew C. Marshal, Advanced Composite-5

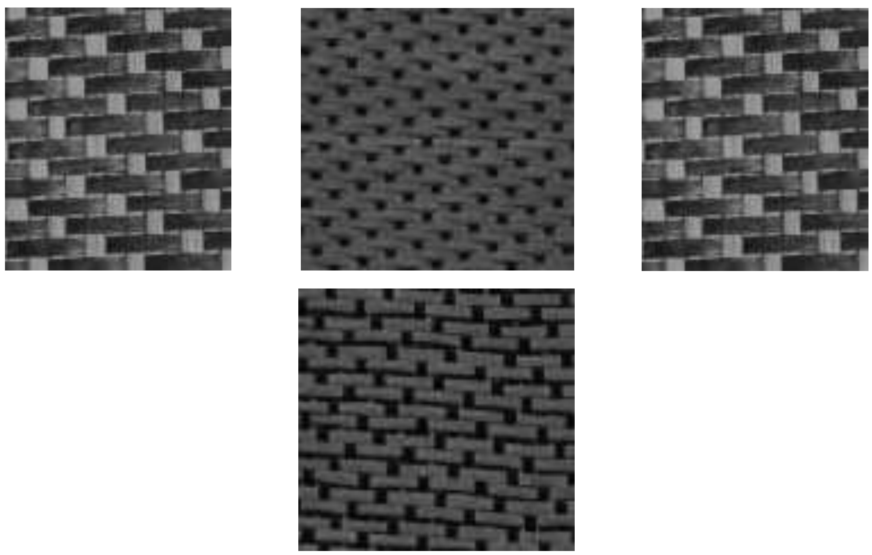
B-2 Fabrics the basic weaves:

Advanced composite fabrics used the same configuration and nomenclature as the conventional clothing factory manufacturers. Such terms as Plane weave Twill or satin weave, Basket weave or Leno weaves are standard to the industry. A sample of this can be seen below fig 18, fig. 18a. and 18b.



A-Plain weave B-Basket weave C-Twill or Satin weave D-Leno weave

Figure No. 18 Weave patterns (*Composite Basics-5*, Andrew C. Marshall)



1 Twill unidirectional 2 Satin 3 Satin basket 4 Crowfoot

Figure No. 18a Advanced Composite Materials Inc. www.a-c-m.com

The plain weave ('A' above, 'a' bellow and 2 above) is the most simple weave pattern, with each strand going alternately over and under the crossings rants. The example shown above uses a plied yarn made up of two smaller yarns twisted together. This gives the weave a balanced fiber pattern of over and under each other. The basket weave ('B' above, 'b' bellow and 3 above) uses 2 yarns next to each other, in place of a single yarn, to make a plain weave. The Twill or satin weave ('C' above, 'c' bellow and 1 above) has one-yarn crossing over several yarns before going under a single yarn. If it rides over two, it is Twill. If over three or four, it is a Crowfoot (4 below) and if over more than four, a Satin. The Leno weave ('D' above, 'd' bellow) is an open weave, with considerable space between the yarns; this style is used to lock the yarn in position. This permits handling of the fabric with a minimum of displacement of the yarns. ‘e’ bellow shows the leno weave with a more secure over and under pattern. The next figure shows the convention nomenclature for placing the yarn.

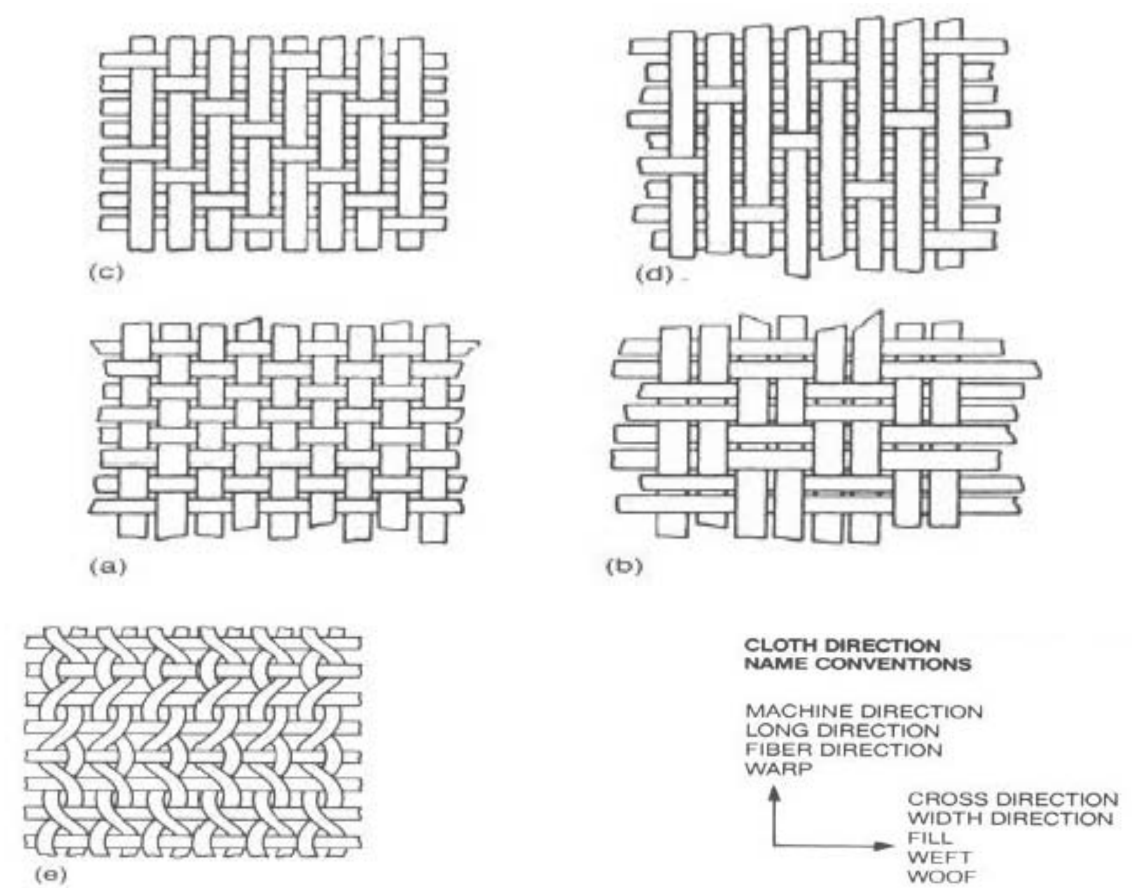


Figure No. 18b Weave Patterns,*(Composite Materials Handbook, Mel Schwartz)*

B-3: <u>Composite Tapes:</u>

Composite tapes are actually composites strips. These strips are made up of a series of single filaments or yarns placed side by side and bound together with a pre-preg matrix (a temporary bonding agent used to hold together the filaments until it is permanently bonded for use), which requires refrigeration until it is ready for use. Once the tape is formed in the proper width it is impregnated with the base matrix and rolled into a prescribed length. (The "tapes”, will vary in width as well as length per the required specifications.) Their application is very similar to conventional adhesive tape see fig19 below, in that it is an applied strip with the final bonding matrix being applied above it, thus binding the “tape” to the surface of the material needing reinforcement or repair. Some color can be applied to the tape, however, it is usually a combination of the color from the composite fabric and matrix been used to form the fabric, see fig.19, (also see fig. 20 below).

Colored fiber tape Selected width fiber tape Carbon fiber tape Kevlar fiber tape

Figure No. 19 Advanced Composites Group, www.advanced-composite.com

Carbon fiber tape applied to reinforce a highway bridge overpass column.

Figure No. 20 Advanced Composites Group, www.advanced-composite.com

B-4 **Mat-fiber:**

Mat fibers are in actuality, chopped strands (also called "whiskers" or "continuous strand mat-CSM)[2] shaped into a single long sheet similar to the other fabrics used as advanced composite. These "mats" Fig. 21 are usually made of fiber glass, Kevlar©, carbon fibers, or any other composite material that is desired. These fibers are typically chopped into short lengths, usually 0.125 to 2 inches (3.2mm to50.8mm) long (see fig 5 above). These chopped strands are available with different sizing for compatibility with most plastics, the amount and type of sizing has a major influence on the integrity of the strand before and after chopping. The strands which have a high integrity are termed as been hard, and strands which separate more readily are termed as been soft. Chopped strands are usually used with premix and wet-slurry molding, as well as reinforcement in thermoplastic molding compounds. Usually hard strands are sprayed simultaneously

2 *A Practical Guide to Composites*, ©Multi-Sport Composites

Part III – The Matrix and Bonding of ACM's

ACM Bonding

Bonding of ACM's is simply the process by which the "glue" is applied to hold all the elements of an ACM together so as to perform "work". The difference in this instance is that the "glue" is called a "matrix", this matrix is made up of a number of chemical elements. These chemical elements are specifically chosen for the materials, environment and function the composite is to perform in and with. These matrices are generated from organic and inorganic compounds. In this instance consideration is also given to the ACM as to its organic or inorganic characteristics.

As noted above the bonding of these materials is highly dependent on the composition of the materials to be used and the environment it is to be used in. However what is more critical is the function of the materials. Is the component material to be made stiff or will it be pliable? Does it have to resist the forces of expansion or contraction? Or is it to cover and conceal a piece of equipment? Does the ACM have to resist electrical current or is it to enhance the flow of electricity in a particular fashion? Will the ACM have to withstand extreme cold and or extreme heat and for how long? All of these issues need answering to determine the matrix to be used as well as the actual make up of the ACM itself.
As each of these (and many more) questions receive an answer the characteristic of the matrix is defined to the point of actual determination of chemical elements and curing process to be used. The bonding process is highly involved with how the ACM is treated, cut, and placed in position for bonding. A determination has to be made as to the use of a pre-preg (an ACM fabric pre-impregnated with an additive to enhance a particular characteristic) composite or not. What is the configuration of the fabric or yarns/filaments? Are these fabrics placed parallel to each other or are they placed in a specific angle to the adjoining fabric for maximum stress distribution?

When initially designing and determining the materials to be used in the fabrication process (figure 16) several pieces of information are required to be at hand

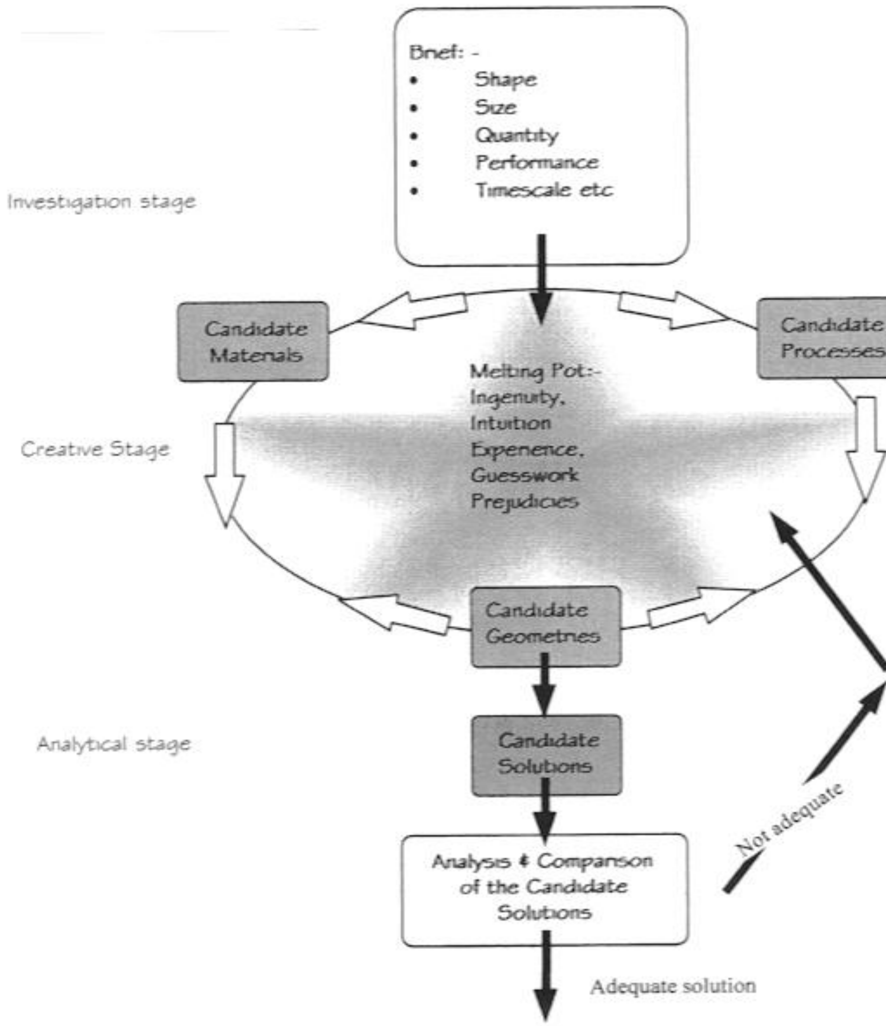


Figure No. 21 The material design process
Composite design Manual JA Quinn

One piece of information required in the preparation process is the bonding index. The index is a numeric value given to a material indicating its particular characteristic which is determined through various types of methodically applied and conducted tests. These tests are conducted by the Associated Standards for Testing Material (A.S.T.M.) to determine the tensile strength (among others) needed for the bonding to be successful during normal loads application.

In determining the Bonding Index (BI)[2] we must take the square root of the tensile strength in machine direction (MD) (direction of pull force) which is given in Newton/sq.cm. (1N=0.225

2 *Introduction to Composite Materials*, Tsai & Hahn

lb./1lb=4.45N) times the tensile strength in cross direction (CD) which is also given in Newton/sq. cm. is then divided by the actual weight of the material (Aw) which is given as gram/sqm. And then multiply by the nominal weight of the materials (Nw) which is also given as gram/sqm.

$$BI = \frac{\sqrt{MD}xCD}{Aw}Nw$$

BI: Bonding Index (N/5cm)
MD: Tensile strength in machine direction (N/scm)
CD: Tensile strength in cross direction (N/scm)
Aw: Actual weight (g/sqm)
Nw: Nominal weight (g/sqm)

At this point we can begin to determine some of the other required characteristics for joining the materials.[3]

1st. Determine the joint type and design.
2nd The fit and sequence of assembly.
3rd The strength needed at the joint.
4th The subsequent environmental exposure of the joint.
5th The material to be used for the bond.
6th The process to be used to complete the bond.

All of these elements must be addressed in a coordinated fashion, as each may have a bearing upon what decision is made regarding one or more of the other items in consideration. The answer to some of these questions will indicate whether high pressure and or high temperatures will be required for the process of joining these materials.

In determining the materials to be used it is also necessary to determine the required thickness of the product to create the most efficient stiffness to the applied load so as not to create access deflection to that applied load.

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3. *Composite Materials Handbook*, Swartz

There are various products in use to create this thickness; they are commonly referred to as "core material". The core material can be made up of any number of material types. They are most commonly made of dense paper, card board, and aluminum honeycomb of various shaped cells (fig. 22). Also in use is the newly arrived polystyrene. In the use of this material, consideration has to be given to the type of bonding agent used as the chemical reaction between the styrene and matrix can cause the core material to dissolve before it is incased in the composite fabric. There are two main issues to be considered in the core type, its stiffness and its weight. The core has to have the appropriate stiffness to prevent buckling or, bending as well as no damaged cells to disrupt the flow of energy when applied to the final product.

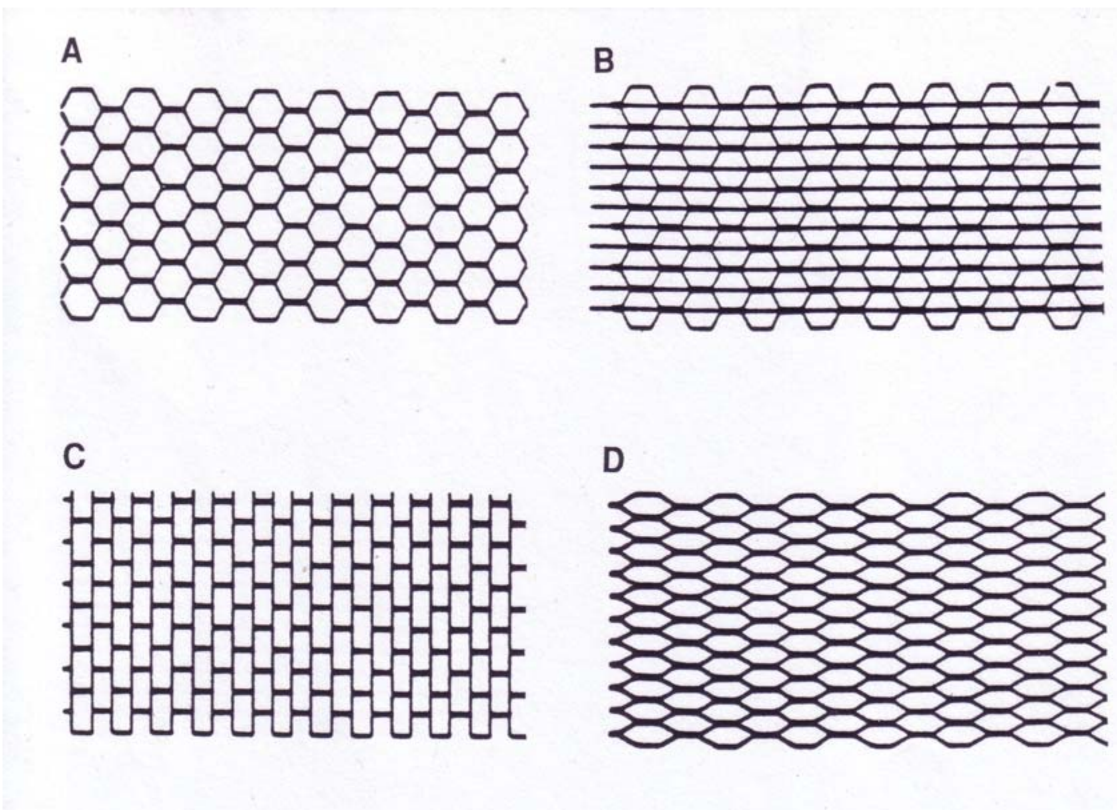

Figure No.22. Honeycomb cell shapes
Composite Basics-5 A.C. Marshall

As mentioned earlier (ACM part B-2) the fabric weave also comes into considerable consideration during the bonding process. Each layer has to be configured to accept the required type of matrix as well as lay flat in the mold without causing wrinkles or waviness in the position placed to shape the object been made. The fabric can be woven from a variety of combination of threads which combine to form the fabric itself. This combination is dependent on the use of the object been made and the type of matrix required to provide the structural integrity of the new component.

The matrix bonding can occur in any of the typically used processes, such as the "open" mold, here a single mold is used where one of the products face is open to the applicator as it cures. The "closed" mold can be described as making a sandwich where the mold in the bread and the composite shape is the filler or the inside of the sandwich. The "wound" process is similar to winding string on a tube and then removing the tube to have an opening through the middle such as a paint roller. While the "continuous" mold process provides a linear shape made to the desired length, theoretically any length.[4] (Fig 23).

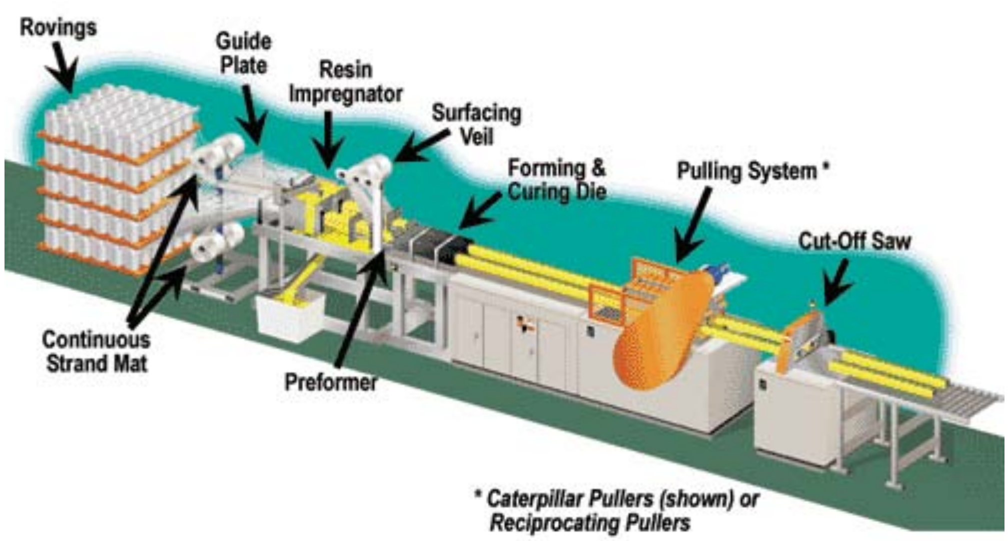

Figure No. 23. The Pultrusion process
Biteam Composites

4. http://www.seecom.org.uk/links.asp

The Matrix

The matrix as mentioned earlier is the bonding agent ("glue") which holds the composite fabric together. In order to develop this bonding agent a number of factors have to be taken into account. Other than the typical structural analysis required for distribution of loads and load path, with ACM's an analysis has to be performed on the fabric (individual layers to be combined) itself. In performing this analysis "Hooke's Law" comes into play F=k x u whereas F = applied force, u =the deformation of the elastic body, and k as the spring constant. Hooke's Law merely states that deformation of a material is directly proportional to the stress applied. In other words if a 10 lb. load causes a deformation of 12 inches in a material, than a 20 lb. force will cause a 24 inch deformation in that same material. Using this fact we can now develop an analysis profile of the fabric we intend to use for the structural member.

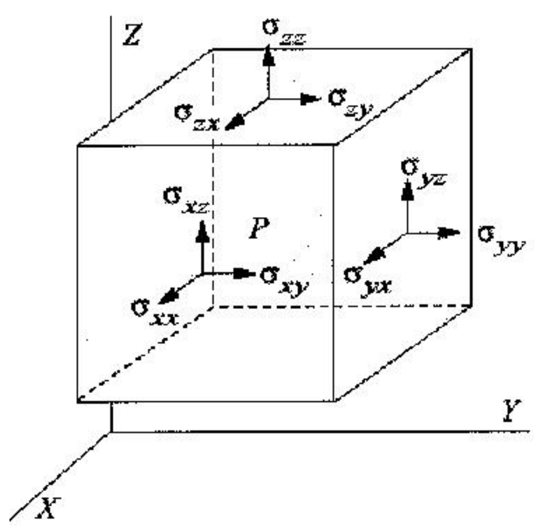

Figure No 24. Stress matrix

Hooke's Law - Introduction to Composite Materials, Tsai & Hahn

The fabric deforms in a number of directions (fig 23). Based on the three dimensional Cartesian grid each plane of the fabric deforms in three different directions, and each of these directions provides the required stress data in the analysis process of the material (fig 25) been considered for use in the structure.

$$\begin{bmatrix} \sigma_{xx} & \sigma_{xy} & \sigma_{xz} \\ \sigma_{yx} & \sigma_{yy} & \sigma_{yz} \\ \sigma_{zx} & \sigma_{zy} & \sigma_{zz} \end{bmatrix}$$

Figure No. 25. The basic stress matrix

Hooke's Law - Introduction to Composite Materials, Tsai & Hahn

The grouping of the nine stress components is known as the "stress tensor" (or stress matrix). In a more generalized laymen's term of Hooke's Law to three dimensional elastic bodies states that the 6 components of stress are linearly related to the 6 components of strain. Written in the stress-strain matrix form, where 6 components of stress and strain are organized into column vectors can be seen in Figure 26.

$$\begin{bmatrix} \varepsilon_{xx} \\ \varepsilon_{yy} \\ \varepsilon_{zz} \\ \varepsilon_{yz} \\ \varepsilon_{zx} \\ \varepsilon_{xy} \end{bmatrix} = \begin{bmatrix} S_{11} & S_{12} & S_{13} & S_{14} & S_{15} & S_{16} \\ S_{21} & S_{22} & S_{23} & S_{24} & S_{25} & S_{26} \\ S_{31} & S_{32} & S_{33} & S_{34} & S_{35} & S_{36} \\ S_{41} & S_{42} & S_{43} & S_{44} & S_{45} & S_{46} \\ S_{51} & S_{52} & S_{53} & S_{54} & S_{55} & S_{56} \\ S_{61} & S_{62} & S_{63} & S_{64} & S_{65} & S_{66} \end{bmatrix} \begin{bmatrix} \sigma_{xx} \\ \sigma_{yy} \\ \sigma_{zz} \\ \sigma_{yz} \\ \sigma_{zx} \\ \sigma_{xy} \end{bmatrix}, \quad \varepsilon = \mathbf{S} \cdot \sigma$$

or,

$$\begin{bmatrix} \sigma_{xx} \\ \sigma_{yy} \\ \sigma_{zz} \\ \sigma_{yz} \\ \sigma_{zx} \\ \sigma_{xy} \end{bmatrix} = \begin{bmatrix} C_{11} & C_{12} & C_{13} & C_{14} & C_{15} & C_{16} \\ C_{21} & C_{22} & C_{23} & C_{24} & C_{25} & C_{26} \\ C_{31} & C_{32} & C_{33} & C_{34} & C_{35} & C_{36} \\ C_{41} & C_{42} & C_{43} & C_{44} & C_{45} & C_{46} \\ C_{51} & C_{52} & C_{53} & C_{54} & C_{55} & C_{56} \\ C_{61} & C_{62} & C_{63} & C_{64} & C_{65} & C_{66} \end{bmatrix} \begin{bmatrix} \varepsilon_{xx} \\ \varepsilon_{yy} \\ \varepsilon_{zz} \\ \varepsilon_{yz} \\ \varepsilon_{zx} \\ \varepsilon_{xy} \end{bmatrix}, \quad \sigma = \mathbf{C} \cdot \varepsilon$$

Figure No. 26. The Compliance matrix

Hooke's Law - Introduction to Composite Materials, Tsai & Hahn

Here **C** is the **stiffness matrix** and **S** is the **compliance matrix**. In general there are 36 stiffness matrix components. Conservative materials (the vast majority of engineering materials are conservative) poses a strain energy density function which results into the stiffness compliance matrix to be symmetrical and therefore only 21 stiffness components are independent of Hooke's Law.

This finite analysis of materials allows us to determine not only the exact capacity of the structural member but, it also allows us to determine to what extent we wish to set the factor of safety in the materials to be used.

In the design of most current structural members the safety factor (the point beyond the materials yield point where the material will actually fail) is most often set at two times the actual yield or failure of the structural component. Although at two times the materials yield point, it does not necessarily fail at the safety factor established. The unit can fail before or after the yield point is attained.

With ACM's the yield point is defined and known before the structural member is fabricated. This in part due to the stress matrix analysis of the various fabrics and resins used to manufacture the structural member. Once the matrix is developed and the vector analysis shows the direction of failure an additional reinforcement can be configured to relieve the additional stress, so as to eliminate structural failure Fig. 26.

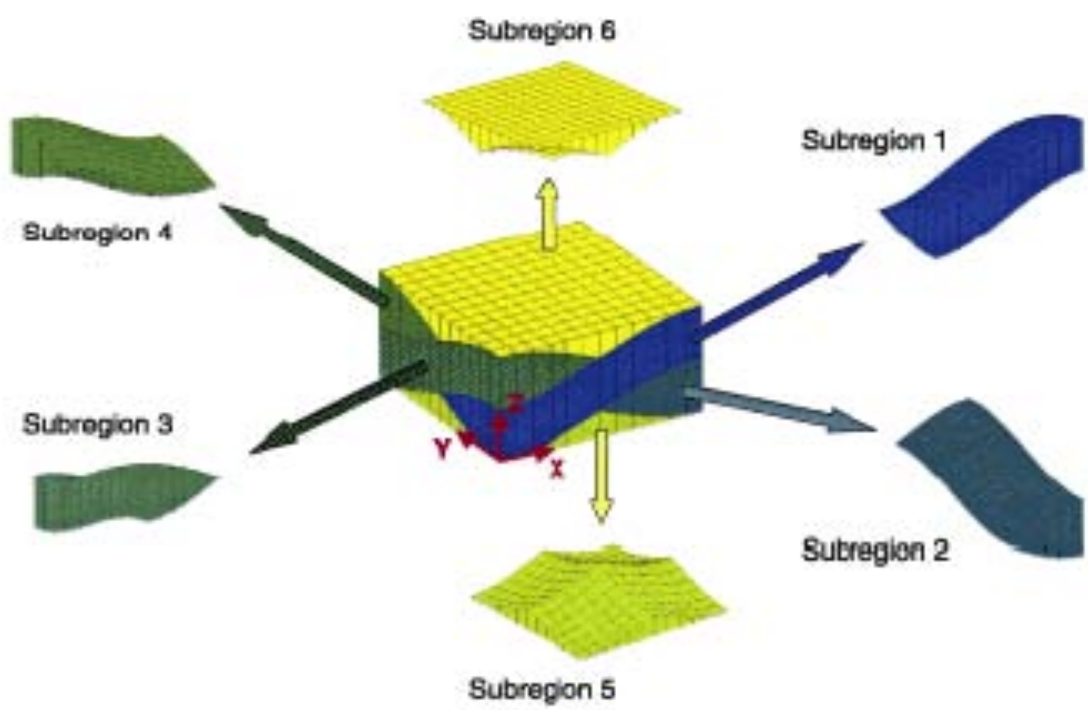

Figure No. 26. Material Stress Regions.
www.Seecom.org.uk

Part IV: Project Context and Setting

The Prototype Concept

The prototype to be developed, will address this innovation on a larger scale. The intention is also to review the possible use of alternative materials and energy sources to power the prototype and perhaps have enough capacity to supply energy to the surrounding neighborhood. As the space and scope of this study has to be limited to the design of the prototype structure, the alternative energy sources will be dealt with in a minimal way. That is by mentioning their possibilities only; as these sources of alternative energy are being continuously developed and refined to achieve more efficiency in creating energy and also to lower their fabrication costs.

Although fabrication costs are always in the foreground of construction it is my contention that as the acceptance of new materials and ideas become more readily accepted their use will increase thus allowing the manufacturing costs to decrease.
For example in the mid 1970's when the first desktop computer was announced the cost of the unit was in excess of $3,000.00, now a consumer can purchase a desktop computer with 100 times the original capacity with a color monitor for less than $500.00. The demand and availability of this one piece of equipment occurred over a mere 30 years.

In addressing these issues initial social policies need to be developed so as to begin the process of establishing community infrastructure, and the social fabric required for the success of this new community. In some communities, close living conditions is already a part of the social fabric and it will have no adverse affect; in other cases the change will occur perhaps slower. It has taken Americans several decades to become accustomed to living in small apartments and condominiums. This change is inevitable as the world's population continues to grow with a predefined amount of land to live on.

The contention is that this prototype can provide a foundation for a more environmentally sensitive and sustainable architectural building type. This type of structure would contribute to the reduction of land acquisition along river banks and the nearby land for building additional structures.

The Community

The Community's History 1975 to 2007

Vietnam has been in existence for some three thousand years, at which time it was known as Van-Lang. It has had to endure the pressures of larger more powerful countries trying to occupy it for its entire existence with the exceptions of a number of short periods when it was self governing. During these periods the country was a feudal state, hierarchically organized but decentralized. The leadership of the various regions was hereditary from father to son; women had no social status within the village. Its longest and most influencing occupation was by China (111BC – 939 AD). During this time some Nam-Viet's (Northern Vietnamese) had attained high political positions in the Imperial Court of China. In 939 AD, Nam-Viet had succeeded in gaining its independence from China. The feudal state of Nam-Viet existed until 1413 when the Chinese invaded and took control of the country once more. This occupation lasted until 1775 at which time the Champa culture of southern Quan-Nam (Southern Vietnamese) were gaining political strength and drove the Chinese out of the now Vietnam.

During these periods the Nam-Viet had adopted Buddhism, Confucianism and Taoism as their form of spiritual guidance, until the French, when they also adopted Catholicism.
It was not until after World War I that the Vietnamese came under some other countries rule and this was France. The French were given control of Vietnam as a spoil of war.
During this period Vietnam adapted and developed many European traits as they began to modernize under French rule. At the turn of the 20^{th} Century Vietnam began to fight for its freedom once more, at which time the Americans became involved (1956 the French left shortly thereafter) in an effort to assist the French, the United Stated turned down Vietnam's leadership request for help in driving out the French. At this point the struggling Vietnamese government in the North turned to the USSR (a Communist Regime) for help. By 1975 the Americans also left Vietnam to determine its own future.

However this was not until the Vietnamese became accustomed to the cultural ways of the West. Vietnam would remain somewhat isolated for the next 20 years when it opened its doors to the outside world as a stable and unified country.

It was not until 1995 when the Vietnamese doors swung completely open that the world realized that Vietnam came out as a Communist country with an overdose of Capitalistic tendencies in the way it conducted its business and its government.[1]

Figure No 27 Southeast Asia (lonelyplanet.com)

Geography

Vietnam is located in Southeast Asia it borders China to the North as well as Laos and Cambodia to the West. Its Northeastern shores are along the Gulf of Tonkin, its Eastern shores along the South China Sea and Southern most shores are along the Gulf of Thailand figure #27. This provides for a warm moderate climate. As one travels father inland the terrain becomes mountainous and somewhat cooler. The highest point of Vietnam is to the Northeast bordering China at 3,144m (10,315 ft.). Vietnam is 329,560 sq. km. (127,243.8 sq. mi.) which provides a shoreline of 3,444 km. (2,140 miles) long (not including its islands)[2].

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1. *VietNam Civilization and Culture 2nd. Ed.* 1994
2. *CIA Fact Book*

Climate

The weather in Vietnam is strongly affected by the monsoon season, and because of this it enjoys lower summer temperatures than most of Southeast Asia. Further inland the mountainous region along its borders with Lao and Cambodia provide the inhabitants there with even cooler temperatures. The average temperature in HoChiMinh City averages between 22^{o}C to 26^{o}C (71^{o}F to 79^{o}F). The humidity ranges around 80% with an annual rainfall a total of 1,979mm (77.9in.) in its 100 rain days during the year. However in Hanoi the capital of the country the temperature drops to 17^{o}C (62^{o}F) in the winter time and has an annual rainfall of 1.8cm (70.8 in.) in its 114 rain days[3].

Culture

The Vietnamese culture is similar in nature as those of the rest of the world, it is an accumulation of traits and customs of people that migrated in, plus its own adaptation of the social needs of the various tribes which made up the country as it came into its own. The flow of people came primarily from Southern China, North-Oriental India and Central Indonesia. Buddhism, Taoism, and Confucianism had a strong influence on the relationship of people to people and people to their lands.

Its language and writing techniques came primarily from China until the French occupation at which time the language was Romanized into its current form. The primary religion and burial customs are taken from India and China. Because of its constant struggle from various occupying forces the Vietnamese developed a strong sense of nationalism and industrialism in order to survive to the modern era. Their adaptation of the modern ways of the West has been considerably faster than any other country in the world. It took Japan from 1945 to the mid 1990’s to fully adapt to the ways of the West while it has taken Vietnam from the mid 1980’s to present to adapt and embrace modern technology[4].

3. *VietNam Civilization and Culture 2nd. Ed.* 1994

4. *VietNam Civilization and Culture 2nd. Ed.* 1994

Land use, Current and Future

Since 1975 Vietnam has been somewhat on its own. What I mean by this is that it has not had to fend off any foreign government trying to help neither the North nor the South of Vietnam be of two different forms of government as it has in the past. The culture has had to become reacquainted with itself, and try to understand each other's desires for self rule.

The North did not go in the very next day after the Americans left and kill and take everyone's land in the southern region. Although there most likely was some snatch and grab of prime properties.

The only reason for mentioning this is that since 1993 when Vietnam opened its doors to the world it has followed only one program for enhancing its economy, that is; it has followed the American tradition of Capitalism. This is not surprising as Ho Chi Ming, who began the unification of Vietnam and the fight to extricate themselves from French rule, was a Harvard Law School graduate. He used the U.S. Constitution and its legal system as the blueprint for uniting Vietnam.

My reason for mentioning all of this is that for an architect trained in the U.S. and Europe it became quite simple to understand the" rules of engagement" for doing business in Vietnam.

Over 95% of the people in Vietnam own their own homes and an equal amount are high school graduates. As the years have gone by more and more Vietnamese are attending school in the U.S. and returning to run various businesses there.

A foreign entity can operate and build an independent business but it cannot yet own land as it can here in the U.S. or in other countries around the world. The government does allow groups to form and develop parcels of land of varying size, but the land is leased to them for a specific number of years (usually 25 to 50 years) depending on the particular project and its value to the growth of the economy.

In the last 15 years most of these projects have done quite well and produced more interest in the construction of infrastructure projects as well as other commercial endeavors brought to the table.

Hanoi is the capital of Vietnam and the major forces of the national government operate from there. However, HoChiMinh City (HCMC) is the power house that operates the economy. Most of the foreign groups operating there have their main offices here, and because of this HCMC has developed and grown by leaps, and bounds. Currently it sprawls over an area approximately 40 by 40 Kilometers (25x25 miles).

Over the last twenty-year's HCMC has had an influx of more than seven million people move in to live and work. The government has been very diligent and industrious as to where it has been allowing people to build new homes. However as new homes and businesses become active the need for additional infrastructures has become more in demand.

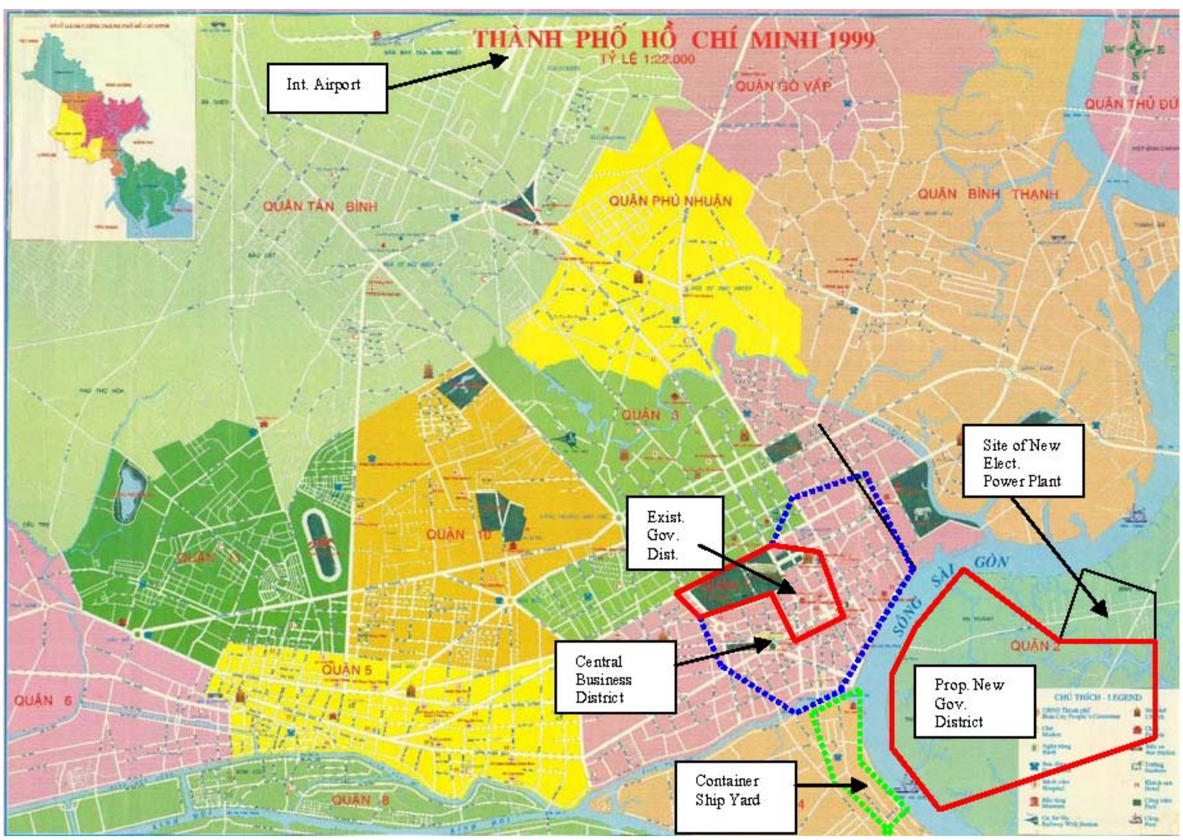


Figure No. 28 *Nha Xuat Ban Ban Do*

As can be seen from the map of HCMC (fig – 28) above the city appears to have very few thoroughfares, but these are just the major avenues of the city. All of its secondary and tertiary street's are too numerous and too small to be shown on a map. See fig – 29.

Figure No. 29.   *Googlearth.com*

The areas outlined on the map, shows the various major government and business districts. The existing government district (which is outlined and noted within the "L" shaped red area in the center bottom of the map) has become encapsulated by the ever growing business district, (which is marked with the line made up of blue dots). Alongside this area is the old traditional sea port that has given this city its life and wealth. As can be seen, there is no place to expand for either the government, or the commercial business.

The red outlined area in the bottom right hand corner of the map is the proposed new government district. As can be seen from the aerial photo of this area fig – 2 (bottom right section of the photo) there is a considerable number of residential and commercial establishments to be relocated and accounted for. Keeping in mind that most of these people own the property they live on, and they have to receive an equal amount of land in size and value before they can be relocated.

The area just above and to the right of the new government district will be the location of the new power plant been considered. In figure #2, this is the green area just above the new government district. The area on the left in figure #2 is the actual “down town” of HCMC. To see the actual density of this space one needs to look at fig. # 30 (below) which is a roof top view of down town.

Figure No. 30 Carlo Priska

From this roof top view one cannot tell that there are streets of any size in the city. Nor can one tell where one structure starts and one finishes with the exception of the occasional mid rise of the few high rise buildings built in down town HCMC.

The primary streets are quite large and can accommodate a great deal of traffic, and yet they still become heavily congested during daily work rush hours, as can be seen in the photo in fig # 31 below.

Figure No. 31 Carlo Priska

While fig. # 30 above shows a rooftop view of a major intersection as pointed out below in fig. # 32 (the black arrow) it is very difficult to distinguish all of the other streets.

This particular intersection has four, 4-meter (16 meters / 52 feet) traffic lanes with approximately 1.5-meter (5’-0”) of sidewalk on either side of the street and no parking along the street. All of the parking for the motorcycles is done on the sidewalk and people have to walk around them.

Figure No. 32 Googlearth.com

The red colored arrow indicates a secondary street. These streets are approximately 8-meters wide or 2, 4-meter lanes one in each direction with a 1-meter (approximately 3 foot) sidewalk on each side of the street. The blue colored arrow indicates a tertiary street which is approximately 3-meters wide with no sidewalks.

The residential dwelling units open into a small courtyard in front which is approximately 2 to 2.5-meters (6 to 8 feet) deep, and no sidewalks. The red arrow indicates the typical residential street which is approximately 2-meters (6'-6") wide. These streets also have no sidewalks, and in most cases the dwelling unit opens directly to the street. In these particular circumstances the motorcycles are parked in the front room which often acts as the space where most of the entertainment is done. fig. # 33 below will give us an idea of the compactness of the city and also the size of the typical residence which is usually 4 to 5-meters (13’-0” to 15’-0”) wide and approximately 14 to 18-meters (46’-0” to 59’-0”) deep. (Field Measurements by Carlo Priska)

Figure No. 33. *Googlearth.com*

Life in HCMC does not end with watching TV after dinner. Most people do their personal shopping in the evening, as most family owned businesses are open until well past 9:00 pm as can be seen in fig. #34.

Figure No. 34 Carlo Priska

The city is in constant motion. Once the sun is down the sweeping and refuses collection starts. This occurs every evening. The trash is collected, sorted and recycled in the manner suited to the materials. Glass, metal, paper, plastic all go in different direction.

Figure #8 below gives us an indication of the development of these ancient roads as they accommodate both old traditions of road side vending and animal traffic, mixed with the new traffic patterns of motorized vehicles. The only change noticeable is that the roads became wider to make room for motorized vehicles.

The road is basically divided into three sections.

Section ‘A’ is approximately two meters (6’-6”) wide. Here the vendors sell their wares as well as everyone using it as a walkway to stay away from oncoming traffic. Unfortunately this walkway is also used to pile up trash and garbage needing to be disposed of as well as storage for pieces of equipment of all kind’s to be used by the government for their particular work in the area. Construction rubble is also stored along this walk until it is ready to be disposed of, when ever that happens.

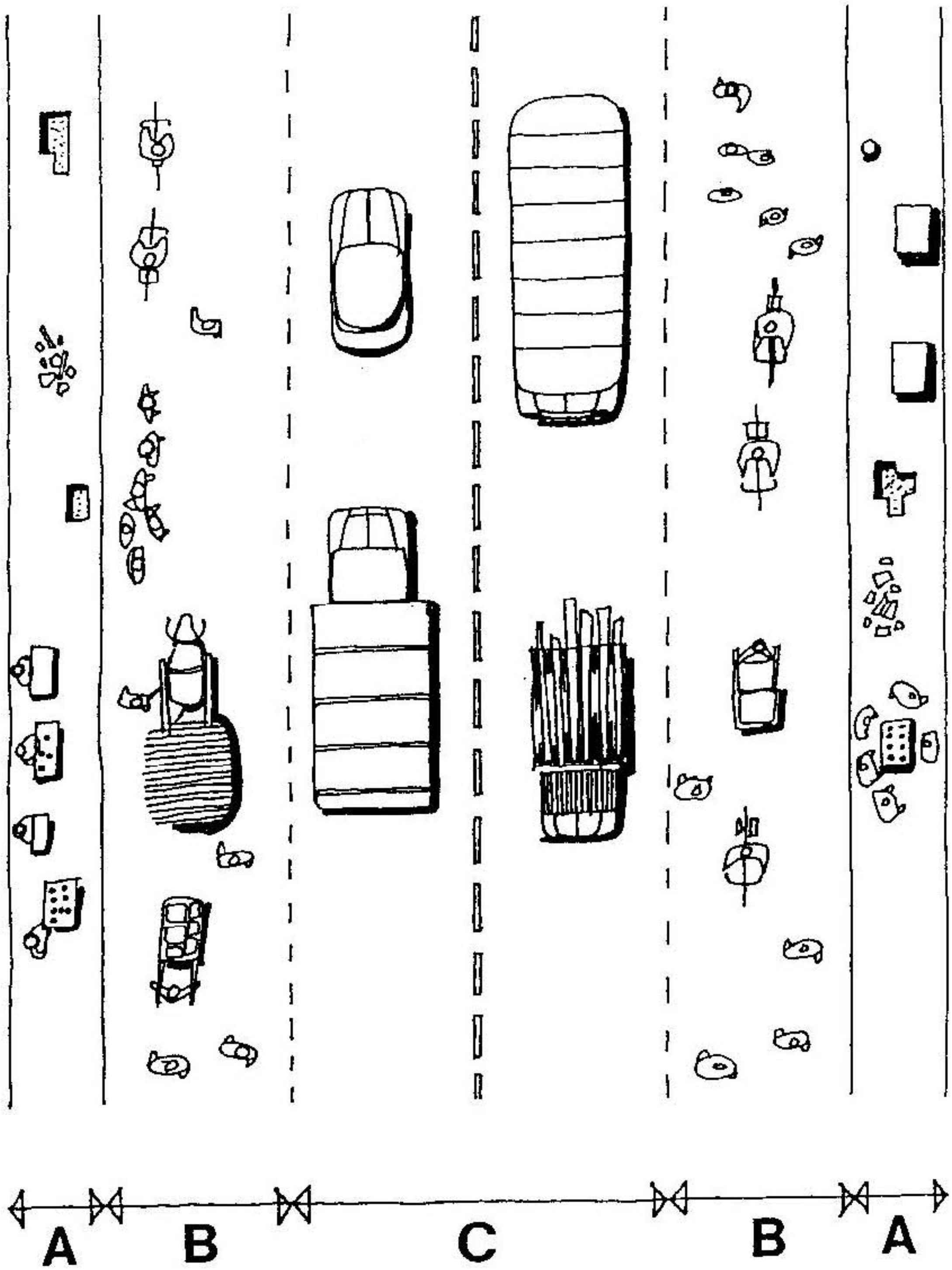


Figure No. 35 *Sub-urban Streetscapes*

Section ‘B’ of the roadway is mainly used by cars, bicycles, pedestrians, parked vehicles, as well as groups of people waiting for a bus or taxi. This area is also used by carts been pulled by oxen and people pushing hand trucks filled to the brim with marketable goods. This area is usually quite dusty and strewed with mud holes.

Finally section ‘C’ the center of the road is used by vehicular traffic running at about 50 to 60 kilometers (30 to 40 miles) per hour. Here the main users are cars, buses, lorries, taxis, and auto-rickshaws. Here accidents occur quite often and are usually very deadly for the smaller of the two in the confrontation.

Some of the small outlying areas of HCMC the province still supports farming of fruits and vegetables, however as the city increases in size the land available for farming is rapidly diminishing. In an effort to reduce the diminishing farmland, the government is allowing the residents to build up rather than out into the farm community.

As the International Building code is been used more and more for residential construction, the city will take on a new appearance as homeowners and businesses build and renovate their spaces.

The entire major infrastructure is been placed under ground. As the roads are been widened and resurfaced. New water lines, electrical power lines, and telephone lines, are buried alongside underground in a watertight configuration. The monsoon season is quite harsh on the city as several centimeters (inches) of rain can fall within a very short period. As HCMC is slightly above sea level, street flooding is very common in many areas of the city.

Part V: - The Proposed Project

Introduction

In preparing to design a prototype community a number of issues have to be addressed, and it is best to list them in whichever manner they come to mind and then prioritize them in a way that can be developed as a "to do" list. Sometimes it is best to simply list them and establish basic thoughts and ideas and let the work prioritize itself. This latter process induces the designer to both write and sketch their ideas. For this project the sketches came well before the written word, and as the words were created the sketches changed and took a life of their own.

The concept started with just a simple bridge for vehicular traffic, however once the full scope of the project came into view (the number of homes and businesses that would be displaced) it became apparent as to what to do with the thousands of people needing to be relocated. The people in the affected community have lived in those particular neighborhoods for many generations. Relocating all of these families would be an enormous undertaking. In order to relocate everyone a large acreage of land has to be cleared for housing. The majority of land around a large metropolitan city like HoChiMinh City is covered by manufacturing facilities, already established neighborhoods or farm land. Manufacturing facilities and neighborhoods will not likely move for anyone. The only space left to take over are the small family farms. In claiming these spaces the supply of food either becomes more expensive or not available.

With such a large bridge (4,000 x 47 Meters/13,123 x 154 Feet) to develop the question comes to mind as to how many dwelling units can be placed on such a span? A more important question is what will be the infrastructure needs. Thus a carefully planned program has to be developed to define and assess the needs since they now become more sensitive to the needs of the people, the community, and the environment all within this dense area of the central district of large large metropolis.

A Prototype Community Development Program

This program (minimal in initial concept) has been developed to outline and fulfill the needs and requirements for a bridge, which will span approximately 400 meters (1,312.332 feet) across the Saigon River in HoChiMinh City (HCMC), Vietnam.

This design program was developed by the author of this paper. The data used in developing this program was obtained over a period of several months; the observations made during this period along with stated requirements in discussions with the director of transportation of HCMC determined the issues to be addressed. The program requirements are itemized as follow;

A) Navigational clearances

A number of activities currently use the Saigon River. HoChiMinh City has a shallow draft harbor approximately five kilometers (3.1 miles) down river. This shallow draft harbor has off shore mooring for approximately 20 ships and docking facilities for approximately 30 ships. Some 40 kilometers (approximately 25 miles) down river is a High Power (33KVA) Electrical line overhead crossing restricting passage to 55 Meters (180.44 feet).

Approximately one kilometer (0.62 miles) up river is a small ship yard. The primary customer served by this group is the smaller river ships. These ships are approximately 100 to 150 meters (328 to 500 feet) long, with a height of approximately 25 meters (82 feet) and 15 meters (49 feet) wide amid ship at the beam. Passing clearance on the river between these ships is a minimum of 30 meters (approximately 100 feet).

The other commercial boats are all under 15 meters (50 feet) long and 4 meters (13 feet) high. Along with this light commercial traffic is the occasional outboard power boats which are less than 10 meters (33 feet) long.

1. Provide a minimum water surface clearance of 180 meters (590.549 ft.)

2. Provide a minimum height clearance of 38 meters (125.00 ft.).

B) Bridge traffic

As the main reason for developing this structure is to accommodate the river crossing of various types of vehicles it is obvious that great consideration be given to the type of traffic required and the numbers of vehicle to accommodate during peak traffic periods. It was determined that we would use traffic figures developed by the U.S. Department of Transportation. This was done due to their extensive studies in this area and long standing expertise in determining traffic flow with various types of surface and weather conditions.

According to the various studies conducted by the U.S. Department of Transportation, allowing for the road and weather conditions encountered in HCMC a 12'-0" wide traffic lane can accommodate 1,000 vehicles at 55 miles per hour (mph). Using these numbers we extrapolated the conversion factor to determine the numbers of vehicles which can be accommodated at 30 kilometers per hours (kph).

The speed of 55 mph converts to 88.51 kph. With this figure in hand we determined a 2.95 conversion rate. What we mean by this is that if we take 1,000 (cars) and divide the number by 2.95 we can assume that 388.98 vehicles should be accommodated within a 4 meter (13'-1½") wide traffic lane. With these numbers in hand we determined that a normal 4m lane can accommodate 389 cars, trucks and busses at 30 kph. There are two lanes of automobile traffic in each direction therefore the bridge can accommodate approximately 777 vehicles per hour in each direction.

The typical lane width for scooters, motorcycles and motorized carts is 2 meters (6'-6¾") this is one-half the width of an automobile lane. The motorcycles allowed by law in HCMC and Vietnam cannot be larger than 150cc with a weight factor of approximately 60 kilogram (kg) or 132 pounds (lb). This engine size is also the governing factor for motorized carts. We are providing two traffic lanes for this type of vehicle. In using the size of the vehicle as one-half the length of a car we are assuming that we can achieve a 50% to 60% increase in traffic flow. With two lanes of traffic in each direction for this type of vehicle we can accommodate minimally 1,165 vehicles of this type.

As there is a great deal of pedestrian traffic in the Government and Central Business District pedestrians have to be accommodated: in this case we determined that the pedestrian walk ways should be secure and separate from vehicular traffic.

This would entail locating these walkways away from the motorized traffic lanes. Therefore the bridge should accommodate the following type of traffic

1. Secured pedestrian traffic
2. Bicycle traffic
3. Motorized cart traffic (150cc)
4. Scooters and motorcycle traffic (150cc)
5. Automobile traffic (SUV as maximum size)
6. Bus traffic (12 passengers to 30 passenger vehicles)
7. Medium weight truck traffic (680 kg. or 1,500lb)

C) Facilities enhancements

As Vietnam is an emerging country it has been determined that some outside assistance would be required to finance and operate a bridge of this size (be that it is not considered to be very large in comparison to most bridges in developed countries). Financing can be obtained through a variety of international sources, however in an effort to minimize the cost to the government we proposed to facilitate some housing and light commercial spaces be built right on the bridge. These spaces can be arranged and paid for as noted in the enumerated items below.

1. Commercial lease space (occupied on a per sq. meter basis)
2. Retail lease space (occupied on a per square meter basis)
3. Recreational space for residential occupants
4. Residential lease/for purchase space
   a. Provide for two/three bedrooms and one/two bath
   b. Occupied on a square meter basis

D) Support facilities

For a structure of this type it is important to understand, and project into the future the types of support systems required to carry the transportation and living spaces into the future without creating a burden on neither the community nor the government. It is therefore important to survey the advances been developed in the infrastructure design of the bridge so as to accommodate the most advanced and sustainable applications available for a new community. A number of these systems are noted below. However as it is always the case for advanced technically oriented projects, observing the development of new ideas is always important in understanding what to implement and what to modify for the purpose at hand.

1. Electrical system (renewable energy source)
2. Telecommunication system
3. Fire-fighting system
4. Potable water system
5. Sanitary sewer system
6. Solid waste recycling system
7. Vehicle parking areas

E) Considerations

As is always the case whenever designing a structure of any type, a great deal of consideration has to be given to the project after it is built. How long is the structure to last? Can we obtain the same materials in the future or do we need to stock-pile some replacement materials? Will it survive the expected weather and natural conditions of the environment in the environs it is built in? What about the aesthetics of the structure will it be something the community will be proud of or will it want to denounce its existence? For a young country with a great deal of natural resources which will cause it to be in the world "lime-light" over the next 100 years these are important issues to address and take note of. The issues below are a few immediate parameters on what is required for the bridge to accommodate.

1. Life expectancy 100 years from completion
2. Provide materials requiring minimal maintenance
3. Light weight and attractive materials
4. Hybrid structural system is acceptable
5. Typhoon winds resistance to 300 kph (217.479 mph)
6. Provide for 10 cm. (3.937 in.) rainfall per hour

The Prototype Design

The Concept:

In creating the design we have to solve four initial problems before entertaining the thought of adding any additional function or activity to the proposed design. In this case the desired outcome is to provide a crossing for various types of vehicles from one side of a river to the other with the realization that “the bridge” will be placed in the heart of a major metropolitan city where every centimeter of ground is occupied by needed businesses and government offices.

The next problem is to determine the required clearance for river traffic to pass without been impeded. The third major issue is what to do with all of the displaced businesses and home owners in the affected community? And finally how do we install the project without causing major disruption of the economic engine that drives a major portion of the country’s economy?

The first problem to be solved is how much space do we need? And what is available for the required ramp up or ramp down to provide the appropriate clearance?

In assessing this problem we know that there are ships crossing limitations which can be used as guidelines in determining the river crossing. Some kilometers down river there is a major 35KVA power line crossing over the river which limits the size ship that can pass underneath it. The ship cannot be more than 38 meters (124.6 feet) in height. This information gives us the possible height for under bridge clearance needed. This clearance is for a ship without the burden of cargo at high tide, as occasionally ships will leave one port for another without cargo, or at least the possibility is there.

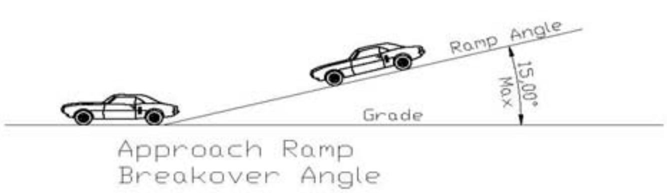
As a member of ASEAN (Association of South East Asian Nations), Vietnam adopted the Annex 11: Road and Bridge Design and Construction Standards and Specification. These rules provide for a standard by which roads and bridges connecting each country. The

Vietnamese Ministry of transportation also adopted these rules for the rebuilding of its infrastructure of roads and bridges. These will be the standards we will be using for our bridge design.

The river is 400 meters (1,312 feet) wide. At the midpoint the underside of the bridge needs to have a clearance of 38 meters. This height is also taking into consideration high tide conditions. Allowing approximately 3 meters (9.8 feet) for the structure itself we now have the needed high point to determine how much space is needed for the appropriate crossing. From known surveys and soundings the deepest portion of the river is the center 60 meters (196 feet), and the typical ship servicing the port is 30 meters (98.42 feet) wide. With this information we now have the size of the space required for a ship to pass under the bridge. The portal needs to be 60 meters wide by 36 meters high at the high tide mark.

In assessing this portal we need to establish that the center of the bridge needs to have a section of road relatively flat for a minimum of 60 meters. At the extreme edges of this "flat plane" the roadway can then start its slope towards the river's edge and the connecting streets.

Having an idea of the profile to follow we can now look at the standards for roadway slopes Figure 36. These standards have been developed over the years by traffic engineers to minimize damage to both vehicles and roadways



Straight Ramps

Ramp Length	<19.8m	>19.8m
Blend Length	3.0m	2.4m
Blend Slope	8%	6%
Ramp Slope	16%	12%

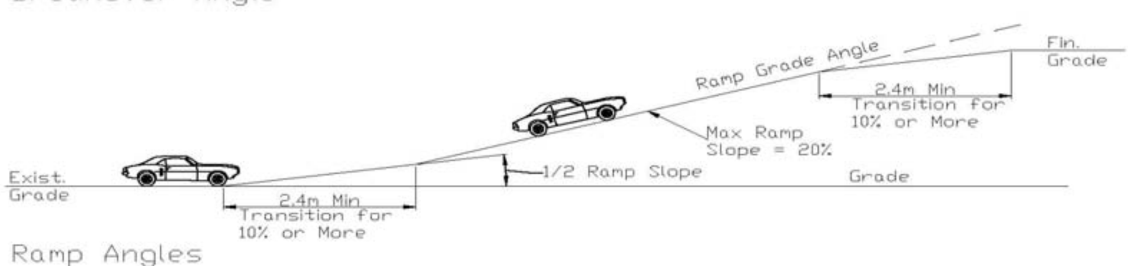


Figure No. 36 Roadway Slope Profiles

Knowing the slopes (6.7%) and distances required to accommodate a bridge clearance of 36 meters at high tide we can now arrive at the space required to safely accommodate traffic from one side of the river to the other.

As previously stated the West side of the river is the core of the business district and the Eastern side is primarily residential which will later be converted to recreational parks and new government buildings. Keeping these two facts in mind alternative for the community have to be developed.

Briefly stated the alternatives are as follows;

1. An elevated roadway to a section outside of the CBD (central business district) where it can return to grade without a great deal of disruption to the community it joins.
2. Provide a sloped roadway which descends to grade along the rivers edge.
3. Follow item #2 and build a structure around the roadway to provide for rentable space around the road to offset construction and operating costs.
4. Consolidate item #2 and #3 whereas the roadway is placed on the outside of the structure and reduces the cost of air quality inside the structure along with possible fire hazards.

Of the items listed above #1 is the most disruptive to the communities on both sides of the river. There is no space available for the roadway to come to grade for a reasonable cost. Item #4 which takes into account both of the preceding thoughts seem to have the best solution in both health and safety considerations. Overhanging a roadway is a solution already in use; all we have to do is look at the various viaducts and bridges already in use throughout the world.

On the West side of the river there currently is approximately one kilometer on either side of the bridge crossing location which is unproductive. This area is vacant and occasionally used by various unlicensed street vendors to hawk their wares which the police have to constantly patrol to keep clear. On the Eastern side of the river where the community is been displaced has similar clearances.

Overlapping a plan of the proposed bridge over an aerial view (Fig. 37) of this section of the city we can see the impact it has on both sides of the river.

Figure No. 37 Proposed bridge design

The Landscape:

We can see here that creating a 500 meter ramp on the West side of the river will heavily disrupt the banks, business, and local and regional government offices. The immediate buildings around MeLing Square from top going counter-clockwise are; an international corporate twelve story office building 2 local government four and five story buildings, a three story international bank building and two twenty story four star hotels. All of these buildings are less than ten years old with the exception of the government buildings and those are about thirty years old. Directly up-river from MeLing Square is the shipyard that is still in use for repairing steel hulled ships. The large boulevard at the bottom of the picture from Southeast to Northwest accommodates various hotels and office buildings all recently built within the past ten years.

Looking at the East side of the river we see primarily single family homes and small shops where the owners and operators of the shops live upstairs from the shop and use the back for storage or preparing their goods for sale pending on the type of service they provide for the community.. The large brown buildings where the bridge connects to the land are old storage warehouses with some manufacturing capabilities, these buildings date back to the 1960's. Also along the river bank there will be small docks to accommodate the receiving and shipping of goods not transported by truck. Most of these goods are food stuffs that are consumed that same day by restaurants and people in the various adjoining communities along the river.

The Bridge:

The primary purpose of this new structure is the crossing of various types of light vehicles (2 to 4 metric tons) from one side to the river to the other. By ordinance any vehicle with more than two axles is not permitted in this core area of the city. Vehicles with more than two axles (with the exception of buses and multi-passenger vehicles) can only travel through the city at nighttime (approximately between the hours of 6:00 pm and 12:00 pm). The reasoning for this is safety, a large vehicle driving at 35 kilometers per hour (22 miles per hour) past someone weighing about 60 to 70 kilogram (132 to 154 pounds and in most cases considerable less) on a 150cc motorbike weighing no more than 60 kilograms (132 pounds) can be quite dangerous. The side wind effect from these large trucks can be devastating, especially if it raining or has just finished raining.

The roadway will have a 13 meter (42 feet 6 inches) emergency road dividing the traffic moving East and that moving West. This is an emergency rout for both police and fire department vehicles. Each side of the crossing will have two 4 meters (13 feet) lanes on the left side (and next to the emergency lane) of the traffic flow. There will also be three 2 meters (6 foot 6 inches) lanes for motorbikes and bicycle. The speed limit on the bridge will be 30 kilometers (18 miles) per hours. A divided, and above grade sidewalk 4.5 meters (14 feet 8 inches) will be provided on the outsides of the bicycle lane away from the car lanes on both sides of the bridge see Fig. 35.

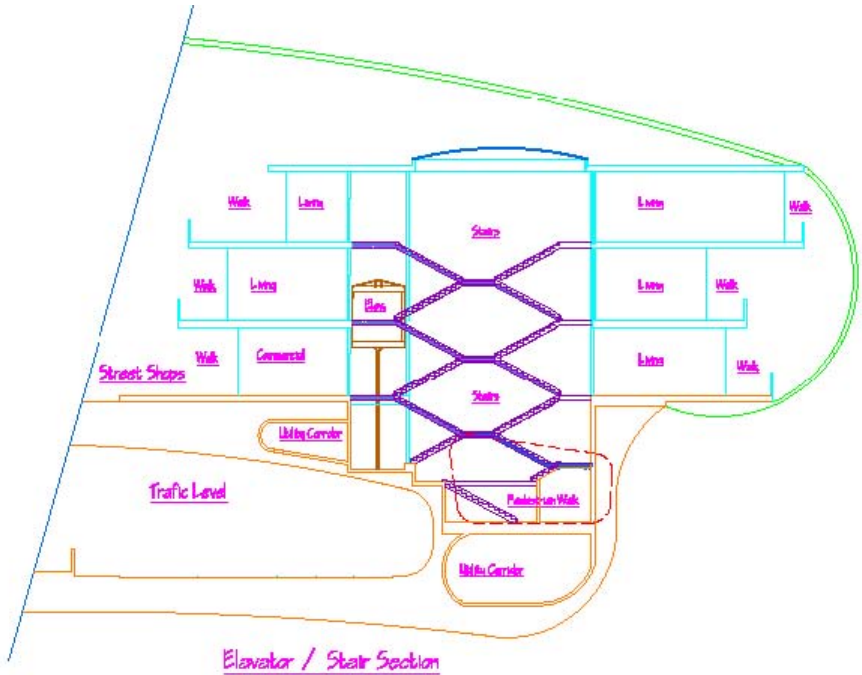
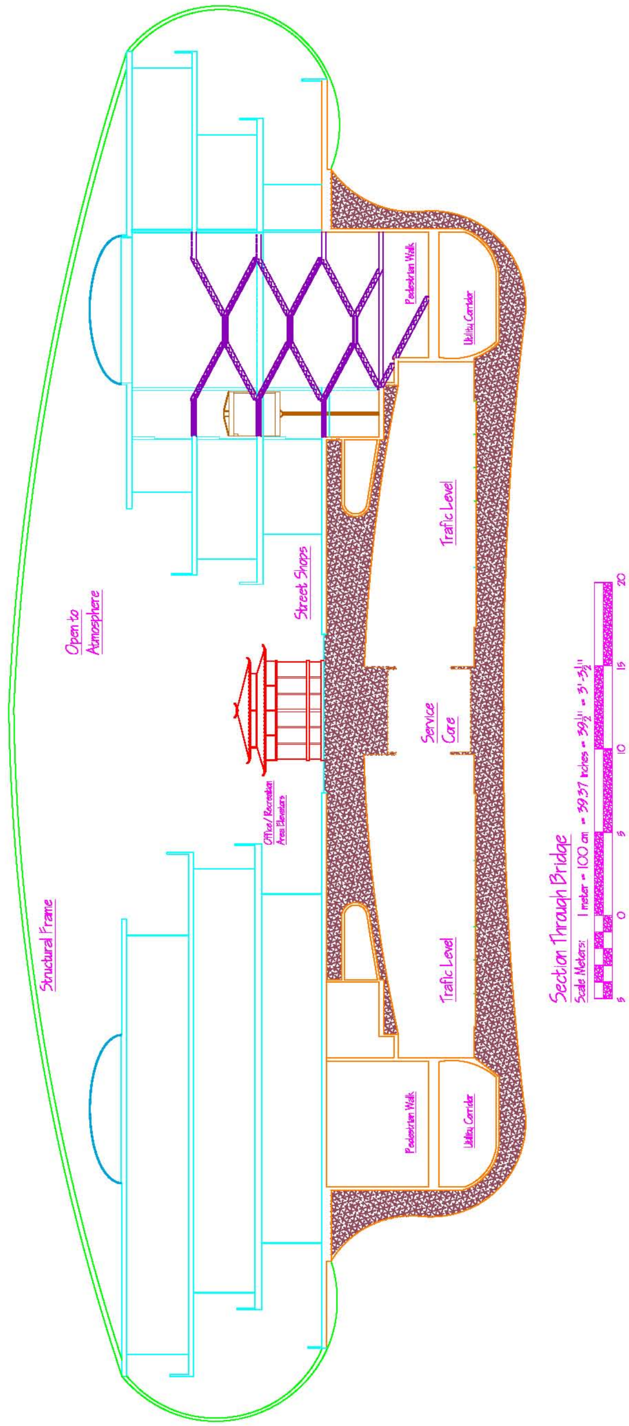


Figure No. 38. Cross section through vertical circulation core.

As can be seen in figure 38 the vertical circulation shafts are connected to the pedestrian cross walk. If there is an emergency that requires evacuation of the structure, the pedestrians and the residents can evacuate without having to be concerned about vehicular traffic. For security reasons once someone exits the exit core they cannot re-enter to go up to the apartments.

The traffic level as well as the service core is fire rated so that the inhabitants and everyone who is on the bridge can exist without any difficulty. As accidents will most likely occur on the bridge the emergency lanes will allow quick removal of the accident should there be a fire on the bridge a fire sprinkler system based on zones would be activated and reduce the possibility of fire spreading through the structure.

Another safety feature for the bridge is that both the floor and the ceiling of the traffic core are designed with explosion proof plates. These plates are designed such that the "ceiling" would resist impact pressure from the inside to the outside. Whereas the floor plates; would have the opposite effect. Should there be a sudden (impact) force on the roadway that section would absorb the force and give way so as to limit the force going to the bridge structure itself.



Section through bridge looking towards recreation area

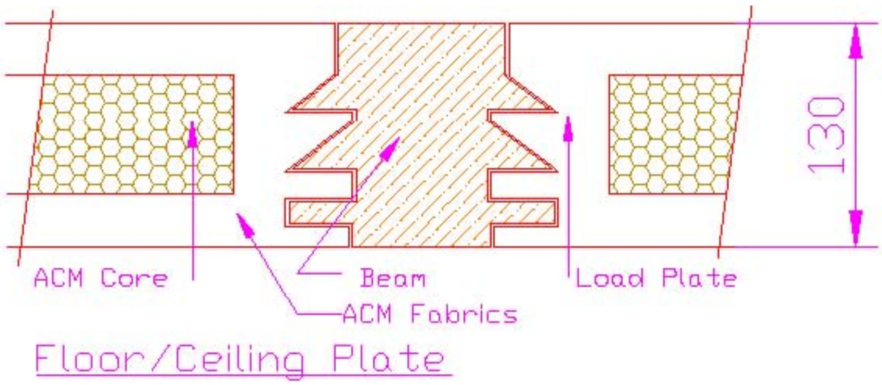


Figure No. 39 Roadway floor & ceiling structure

What we see above in figure 39 is a typical joint between the load plates or what would be the ceiling or the floor. Viewing the detail as if it were a ceiling plate, the additional flanged area would provide the force to resist any additional load. Viewing it as a floor plate we can see that if there were any additional impact force the plates would give way and absorb the impact load.

As would be typical of such new technology a variety of load tests would be required. These tests would also include and undergo various types of weather, temperature and hazardous waste spillage conditions to insure its proper workings.

Along the sides and above the traffic core there are two (each side) utility cores. These cores function in a variety of ways for distribution of power, communication, waste water and potable water. These spaces are also large enough to create emergency control centers, as well as emergency shelters should the need arise. As the region is not immune to hurricanes (monsoons) and other natural disasters to occur here, it is also subject to region wide flooding as it is not but two to three meters (6 feet 6 inches to 9 feet ten inches) above sea level.

The Housing:

The typical residential lot in Vietnam is 4 meters (13 feet) wide by 15 to 20 meters (49 feet to 65 feet 6 inches) deep. Approximately 60 to 80 square meters (650 to 860 square feet). The with of the property in some cases reaches 5 meters (16 feet 5 inches) wide, most of these lots have been used as private shops where the owner lives in the back or above the shop. The option that everyone has to expand their homes is to build up. Traveling through most neighborhoods one would see a considerable number of multi-story structures. In some cases one may well notice three and four story structures.

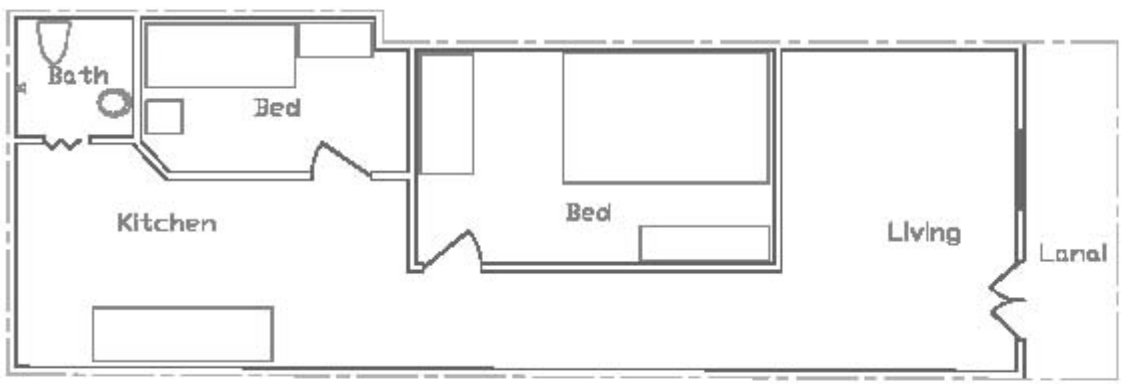


Figure No. 40 Typical Vietnamese residence.

The typical Vietnamese family housed in one of these homes would be made up of the parents and one or two siblings. The extended family would not be very far away, usually within five minutes walking distance. The market (for groceries) would not be more than five to ten minutes by scooter.

Typically the home would be laid out (fig 40) with the front entrance Facing the street or alley way. There might be a small fenced enclosed area just large enough to accommodate the parking of one or two motor scooters. The front room would accommodate the majority of the family activities. This room would be furnished with a small couch a small table and or two or three chairs used to sit around and watch a movie on the TV or sing karaoke, here the family would also entertain guests, play games, have dinner and just relax. The bedrooms are not very large as the only use is for sleeping and dressing they would only have the bed and a wardrobe with perhaps a couple of drawers at the bottom and a small dressing table.

The kitchen would have the basics a countertop propane cook-top, an apartment size refrigerator (as all food is purchased for that days consumption), any utensils, dishes, pots and pans would be neatly stored under or above the counter, and the sink would be just large enough to accommodate the few dishes that are used for a single meal.

Housing on the bridge would be a little more westernized in that it would have rooms with more defined functions, typical of western culture. This would be done to create more efficiency within the available space in the structure see fig. 41.

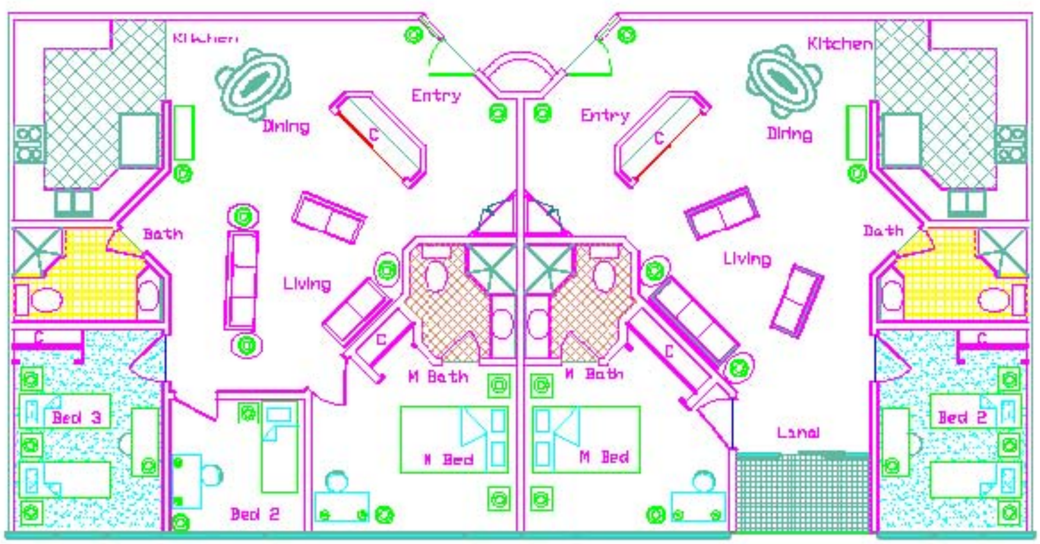


Figure No. 41 Typical 2 & 3 bedroom units

As can be seen in figure 41 the circulation corridor is on the inside between two rows of units, this can also be configured with the corridor on the outside where the bedrooms are back to back; in this arrangement all of the units would be three bedrooms. Each unit is 10 meters (32 feet 10 inches) square, approximately 30 square meters (1076 square feet).

In either configuration the bridge can accommodate 84 dwelling units per level; this will give us approximately 252 units. The adjoining structures creating the anchor points at each end of the structure would house private offices, additional homes or can be developed as hotel rooms for business expatriates.

The Utilities:

As can be seen in figure 25 the residential units have a vaulted shell on top as well as a curved shell on the sides, causing the bridge to have some aerodynamic configuration to alleviate wind pressure on the sides of the bridge. These curved areas are made up of a composite grid which allows transparent solar panes to be mounted; the grid would have a standard profile so as to allow for one size fits all condition. These panels will assist in providing power to the users on the bridge. The solar panels would not be able to provide all of the power needed but as the voltaic technologies advance through the years they can be replaced. As most Vietnamese home are accustomed to using fluorescent light fixtures, it would not be difficult to transition to Light Emitting Diode (LED) light fixtures. The technologies for these fixtures is already available, as well as replacement components for existing light fixtures. Sylvania a leading lighting unit supplier provide various wattage size as well as various colors for light bulb replacement, see figure 42.

Figure No.42 LED Replacement bulbs, www.sylvania.com

A new concept in residential lighting will come into play as with LED replacement lights a combination of colors and light levels will become more easily available with more energy efficiency and lower energy costs. LED light units are rated in Kelvin Degrees (K), an example breakdown of this spectrum follows.

Sunlight at sunrise = 1,800k Sunlight at noon = 5,800 to 6,500K

Fluorescent lamp = 2,600 to 7,500K Candles = 1,900K

White = 6,000K + Daylight White = 5,000 to 5,500K

Cool white = 4,200 to 4,500K Warm white = 2,800 to 3,300K

For a typical room where someone would have two 75W bulbs for lighting, one would need to use three of these lamps; while they operate at 85vac to 260vac they can operate in any country and still use 30 to 50% power.

Additional required power can be secured from the power plant at the northern end of the peninsula. This facility was developed in expectations of the new government center.

The water supply is of course available as the relocation of the existing residences would allow for the water supply needed for the housing on the bridge. Management of the waste water in the newly developed community would be of some concern, the existing system that provides treatment for the existing community is old, under-sized and not very efficient. As the bridge crosses a major river of the region and the national government places a high priority on environmental concerns; and keeping the river clean a new system which allows for the recycling of the waste water would have to be installed. Using aerobic and anaerobic digesters at both ends of the bridge will accommodate the new community above and have enough volume capability to accept the over-load from the adjoining CBD community.

Pedestrian & Vehicular circulation:

The sections of the structure in figure 25 shows in part one of the vertical circulation cores that allow pedestrians to move from one level to the other. The scissor style stair design allows for quick and easy movement from one level to another in the residential section of the bridge. The stairs are 119.15 centimeters (3 feet 10 ¾ inch) wide, this allows for two people to walk down side by side if they wish; and in order to ease the energy used in climbing the stairs the steps are designed to have a height of 15 centimeters ($5\ ^{7}/_{8}$ inches) while the step width is 28 centimeters (11 ¾ inch) this has been seen as a very comfortable rise thread relationship for stair design.

Alongside the stair core there are two elevators, they travel from the upper most living level down to the pedestrian walk which allows people to walk across the bridge. In order to keep the residents on the bridge secure from any unauthorized entry access to the elevator at this level will not be allowed, at this level one can only exit the elevator it does not have a call button for access. Both elevators are 245 centimeters (8 feet 5 ½" inches) deep, and 104.92 centimeters (9 feet 9 ½" inches) wide. This will allow for large packages and furniture to be delivered to the residents above.

While the stairs are designed for a comfortable walk up and down, the passage ways have been designed so that two-way traffic can occur. The corridors are 273.82 centimeters (8 feet 11 $^{7}/_{8}$ inches) wide. In addition to the wide corridors one can also look to the outward facing side and have a view of the river as a screened opening occurs along the distance of the walk. This is to provide a sense of been outside, getting fresh air and at the same time been under cover during inclement weather. The breeze flowing through the openings will allow for a shady and comfortable walk during the hot summer days.

The recreation and office facilities of the bridge have their own set of elevators and stairs fig.43.

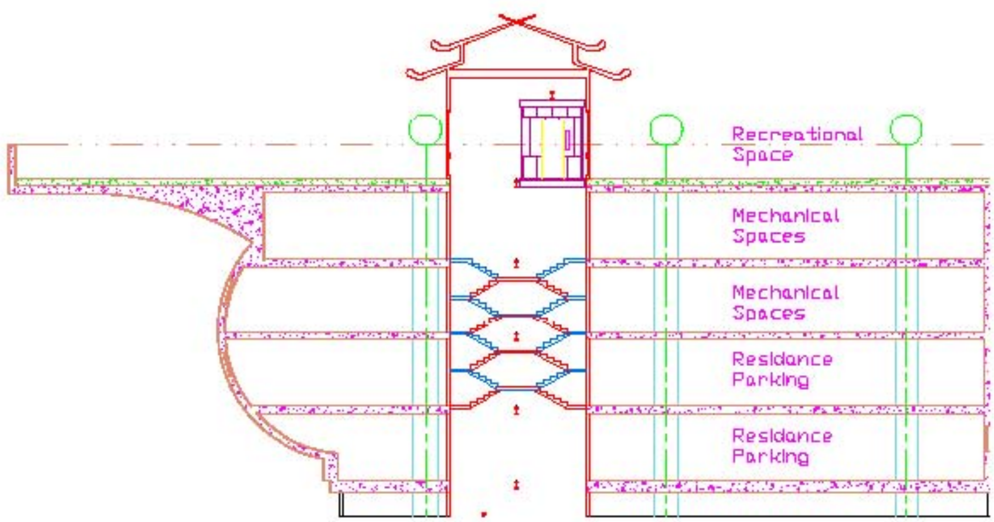
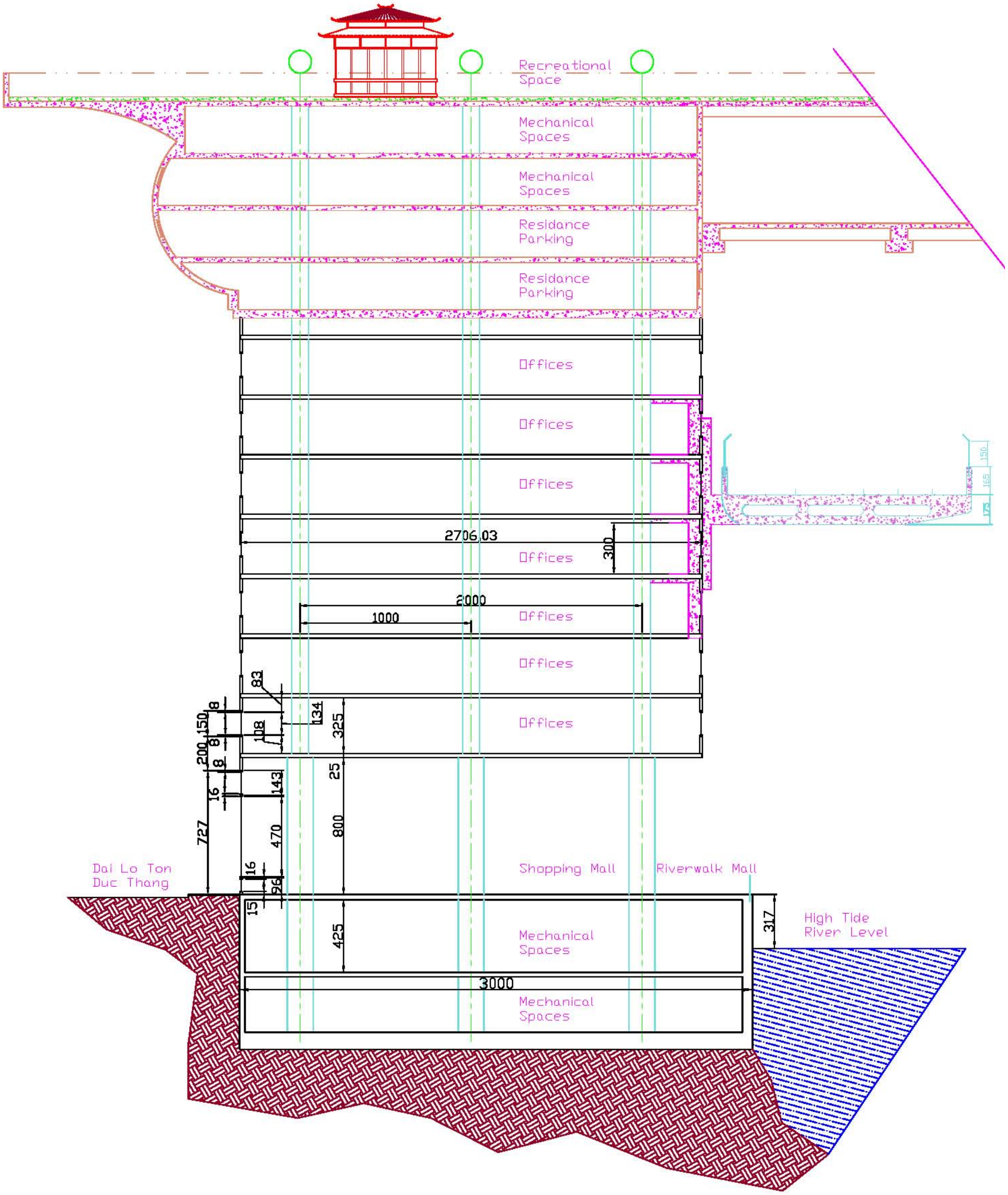


Figure No. 43 Section through Rec. deck elevator & stairs.
(Stairs not shown full height for clarity)

We can see here that the residents will have spaces to park their vehicles and at the same time be able to have an area for exercise and other sports activities the same as any other neighborhood in town. Because of the office spaces below the "park"; this core accommodates four elevators as well as two stair cores which will allow rapid egress if necessary. We can see in fig. 44 how this elevator stair core works. The stairs and the elevators would have the same size profile as those described above.



Section Through Office Tower

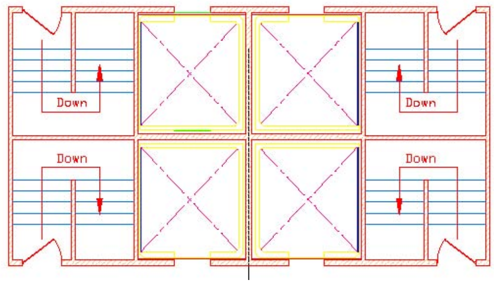
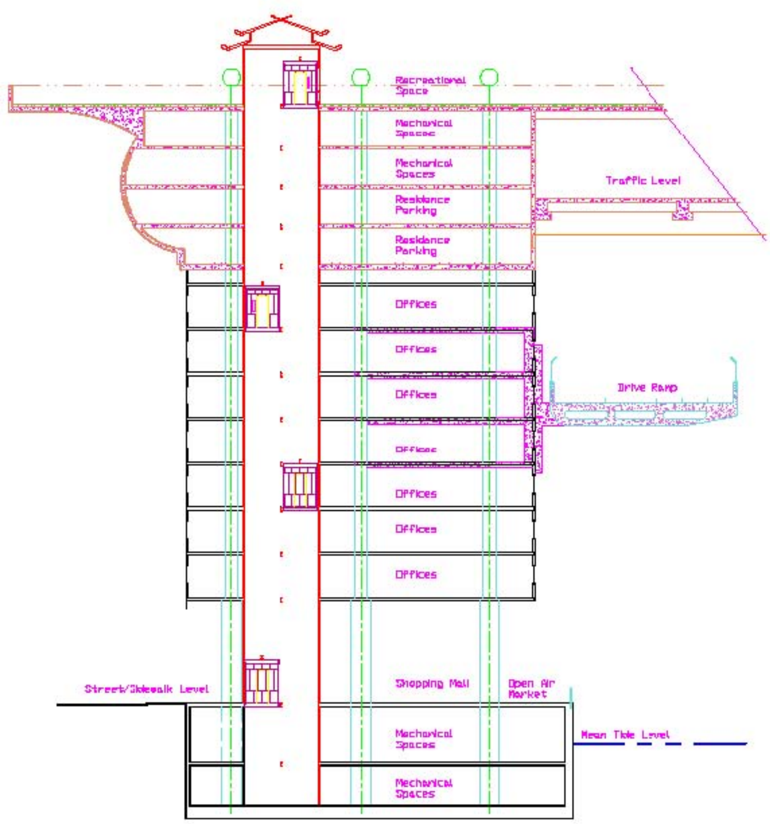


Figure No. 44 Recreation deck circulation core

This core starts on the ground floor and opens to all of the office spaces in the grounding structure of the bridge. As all Vietnamese are able to use any park facility, so too will they be able to use this park on the 14th floor of the structure.

Looking at fig. 45, a section through the office spaces (the ground structure) and the recreation core superimposed we can see how the unit functions with the elevated roadway which will turn and enter the bridge to cross over the river.



Park Elevator Section

Figure No.45 Office/park core section (Showing drive ramp to bridge)

Fig. 46 below shows the relationship of the major traffic arteries of downtown Saigon alongside the river on its Western side. At the right of figure 32 is one of two major streets that pass through downtown Saigon. MeLing Square connects this part of the CBD to the airport and the Northwestern business center. Hai Ba Trung the street that branches off to the bottom left of the paper is primarily made up of commercial establishments with very few residential spaces. As can be seen the bridge roadway (blue lines) forms over 580 meter (1,910 feet) to the center of the bridge thus giving the roadway a slope of about 6.7 percent; well within the maximum allowed by “Annex 11” the ASEAN accord for international transportation routes.

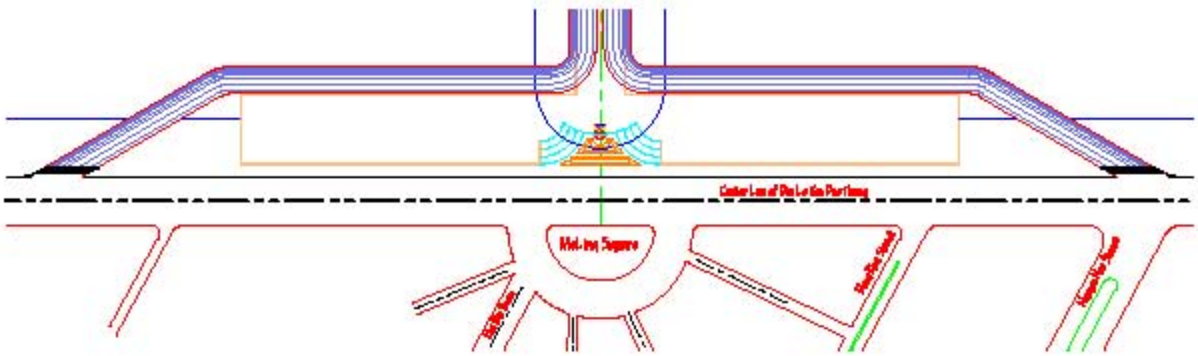
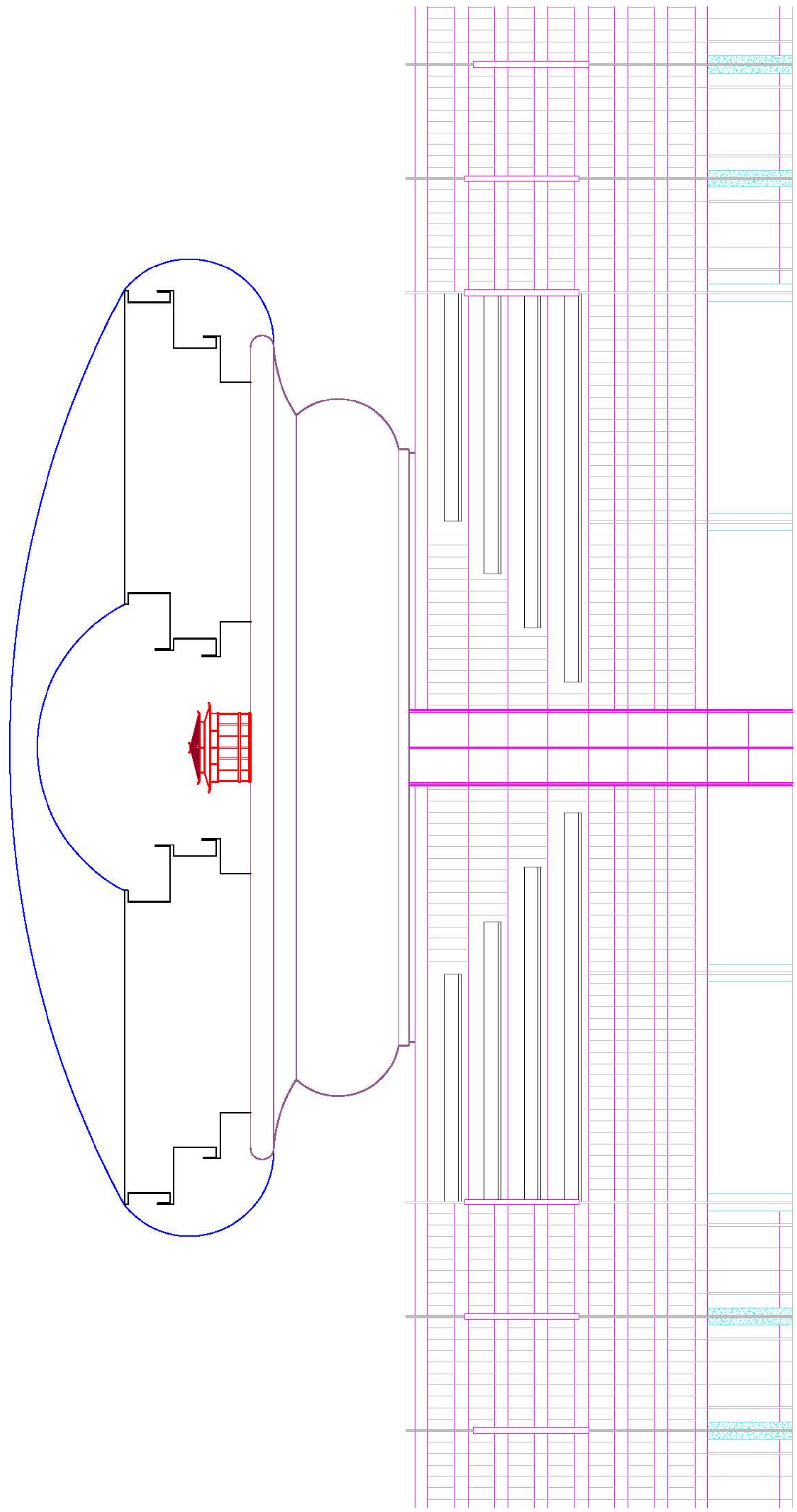


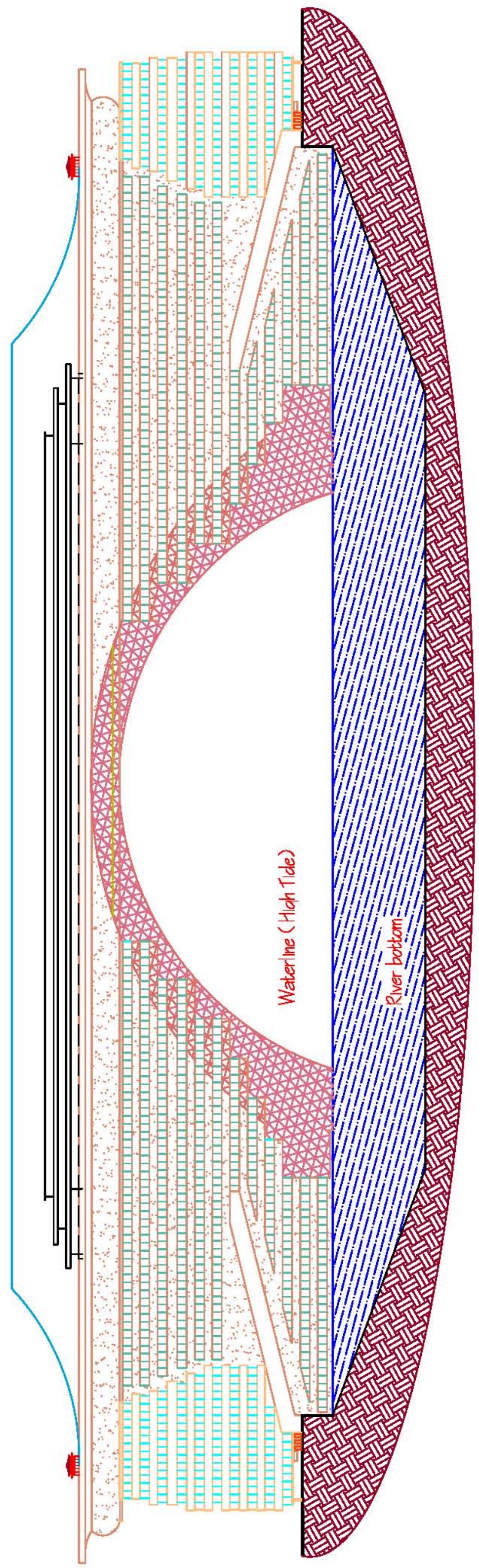
Figure No. 46 Bridge connections to Me Ling Square and the major traffic routes

Figure No. 47 Elevation of the bridge and office ground structure facing Me Ling Square

Fig. 47 above shows the front or street elevation of the office pedestal for the bridge. This particular view does not show the up and down ramps which run alongside the pedestal on the river side, however as the ramps go up there is a slight separation to minimize vibration and noise from the traffic. One of the methods used to reduce the noise affecting the office spaces is to provide double insulated glass as well as providing the circulation corridor with additional sound proofing on the river side of the structure.



Elevation at MeLing Square



Riverview Elevation

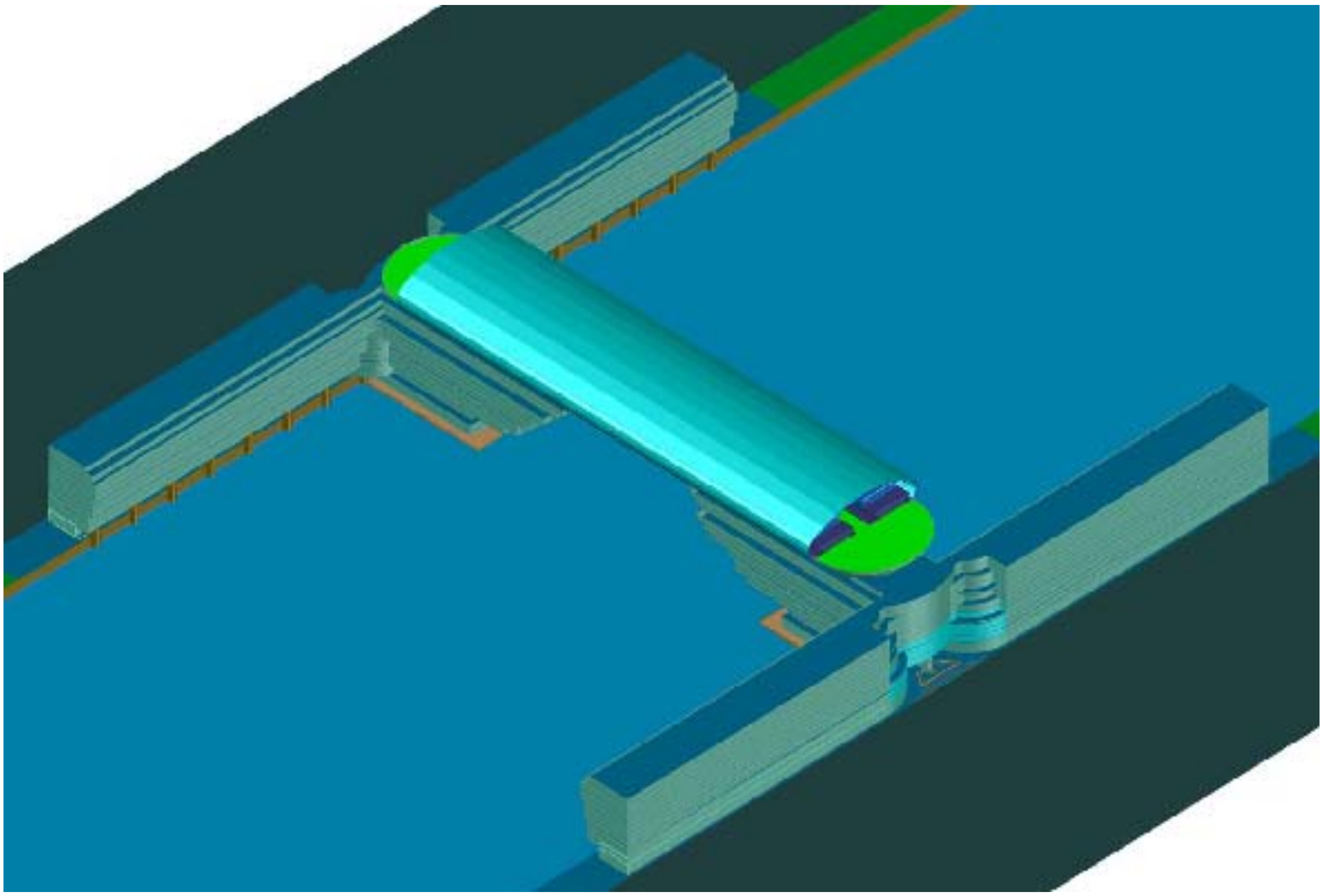


Figure No. 48 An aerial view of the bridge without the roadway

Fig. 48 above is a rendered aerial view of the bridge with the office pedestals on either side of the river and a projected pedestal under the bridge itself. The lower portion of the pedestals would house various types of commercial and retail spaces; whereas the projected pedestal would in itself be high-end office spaces. As Vietnamese are fond of dining and drinking along the shoreline, the lower portion of the pedestal near the water line would have various types of restaurants and coffee shops.

Fig. 49 below shows the project layout as it would appear from an aerial view. The lower portion shows the park area along with the elevator and stairs that service that level. The upper portion of figure 35 shows how the main entry to the office complex is situated, as well as the location of the housing on the bridge itself. The photo-voltaic cells which form the domed roof of the structure is shown as simple straight lines.

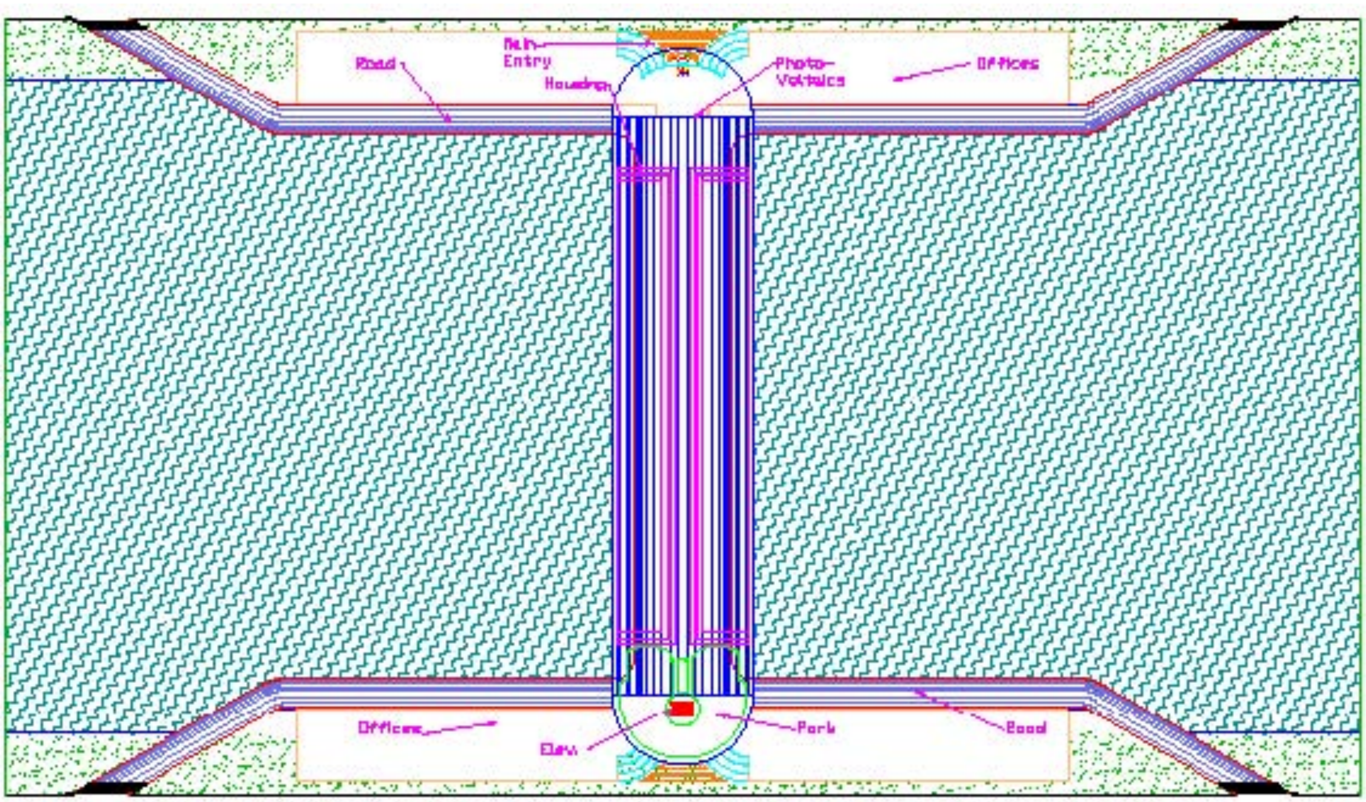


Figure No. 49 An aerial view of the bridge showing carious areas.

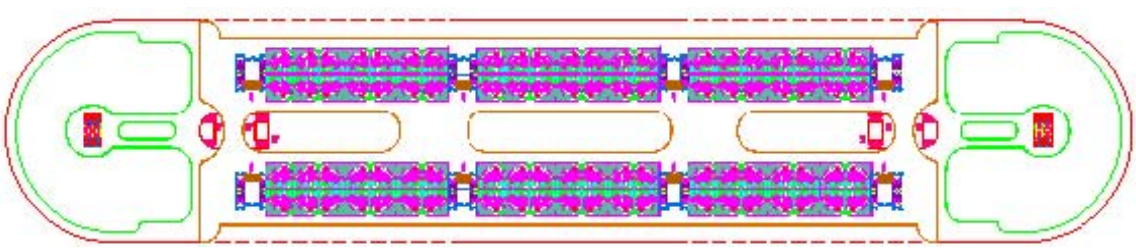


Figure No. 50 Plan of the first living level on the bridge.

Fig. 50 above shows the typical apartment for the residents on the bridge (fig. 41 for enlarged plan). The elevators and stair cores are arranged at 82 meters (269 feet) apart. The actual travel distance for each resident would be about 42 meters (approximately 135 feet) this would be the same distance as most of the walk up apartments built in the West.

The area outside the apartments is all walk able space which residents can also use to exercise and walk around; a favorite early morning exercise for most Vietnamese. Each bank of apartments contains fourteen units, seven back to back.

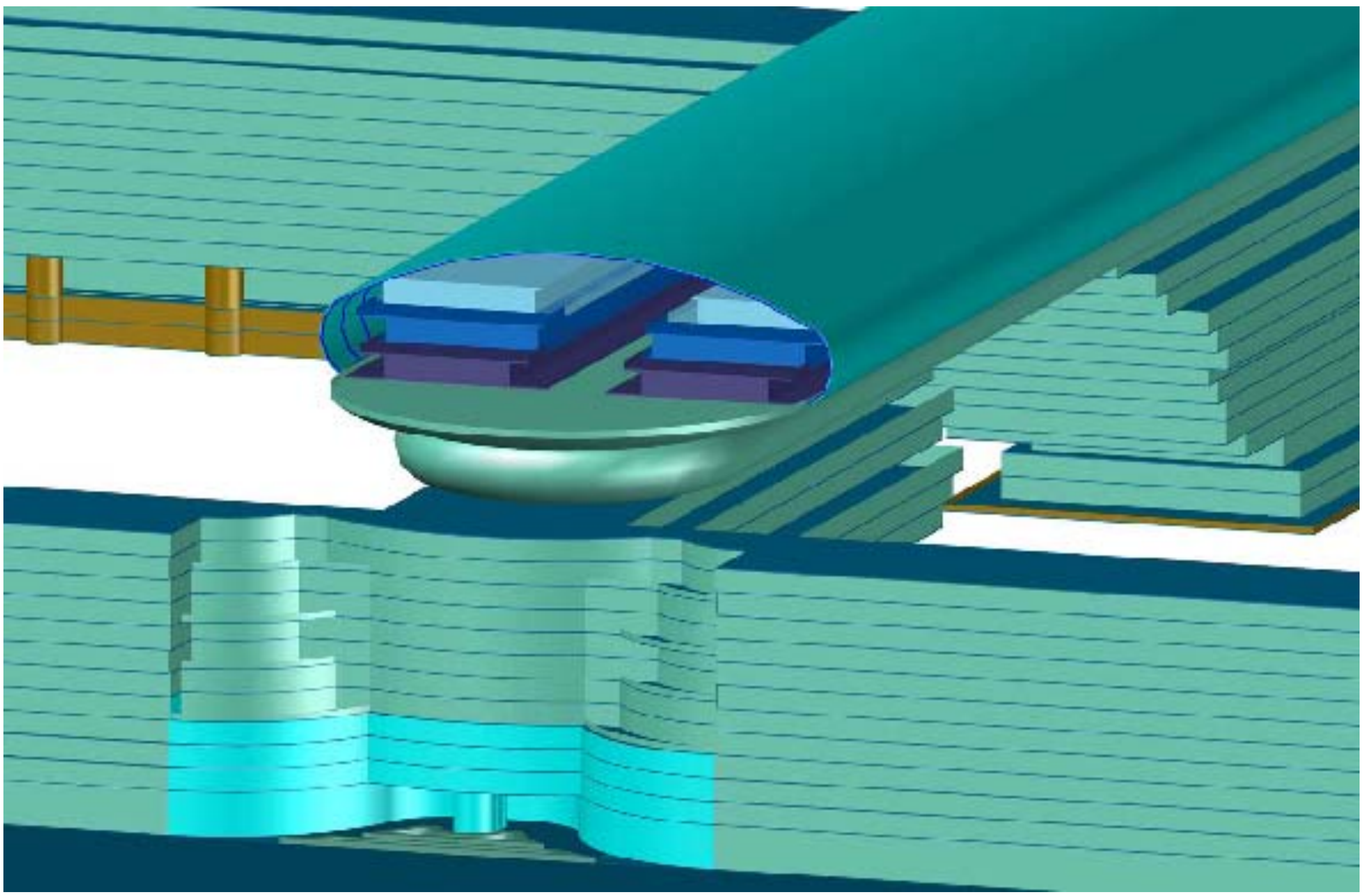


Figure No. 51 Perspective view looking into the residential area and main entry below.

Fig. 51 is an aerial view of the bridge looking at the main entry of the office pedestal and the inside of the residential block up above. Somewhat flattened out in the foreground of the residential block is the park area where children and other occupants can enjoy the outdoors without the concerns of traffic impeding on their play.

Fig.52 to Fig. 57 shows a series of snapshots of a theoretical snap shot of a fly-by of the new community. It clearly shows the total penetration of sun light, air circulation as well as a sense of open space for its inhabitants to have a sense of place and community.

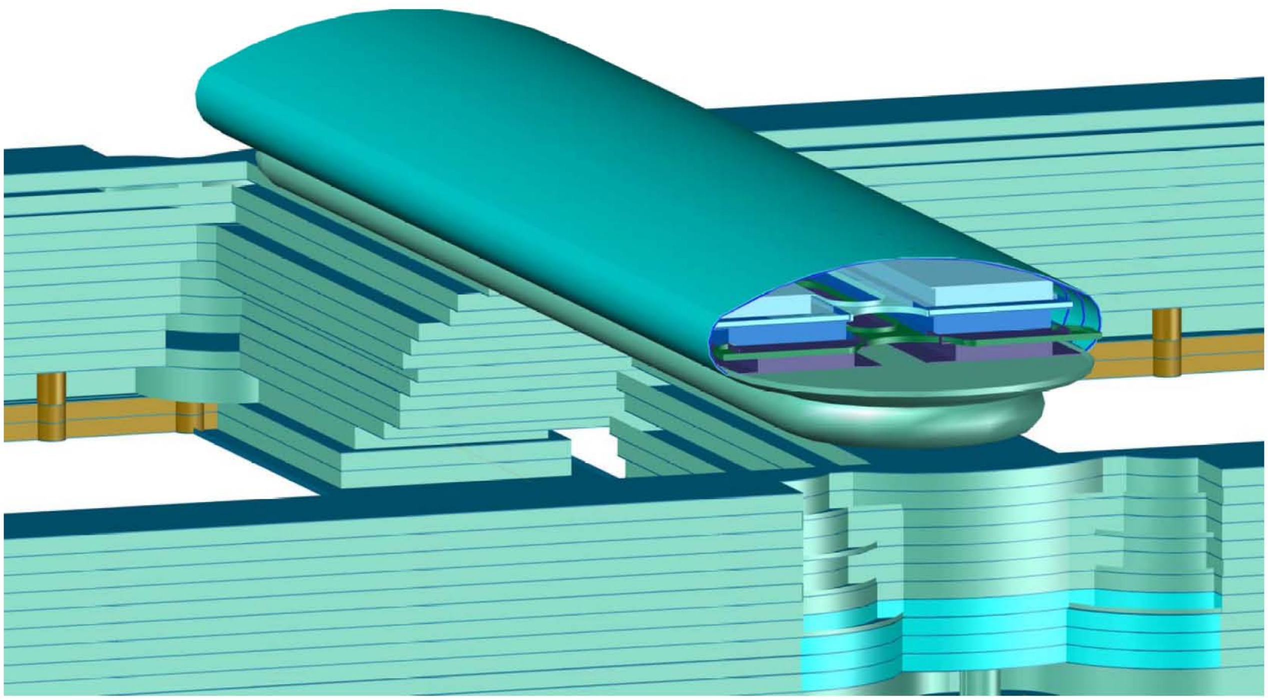


Figure No. 52 MeLing view above bridge level

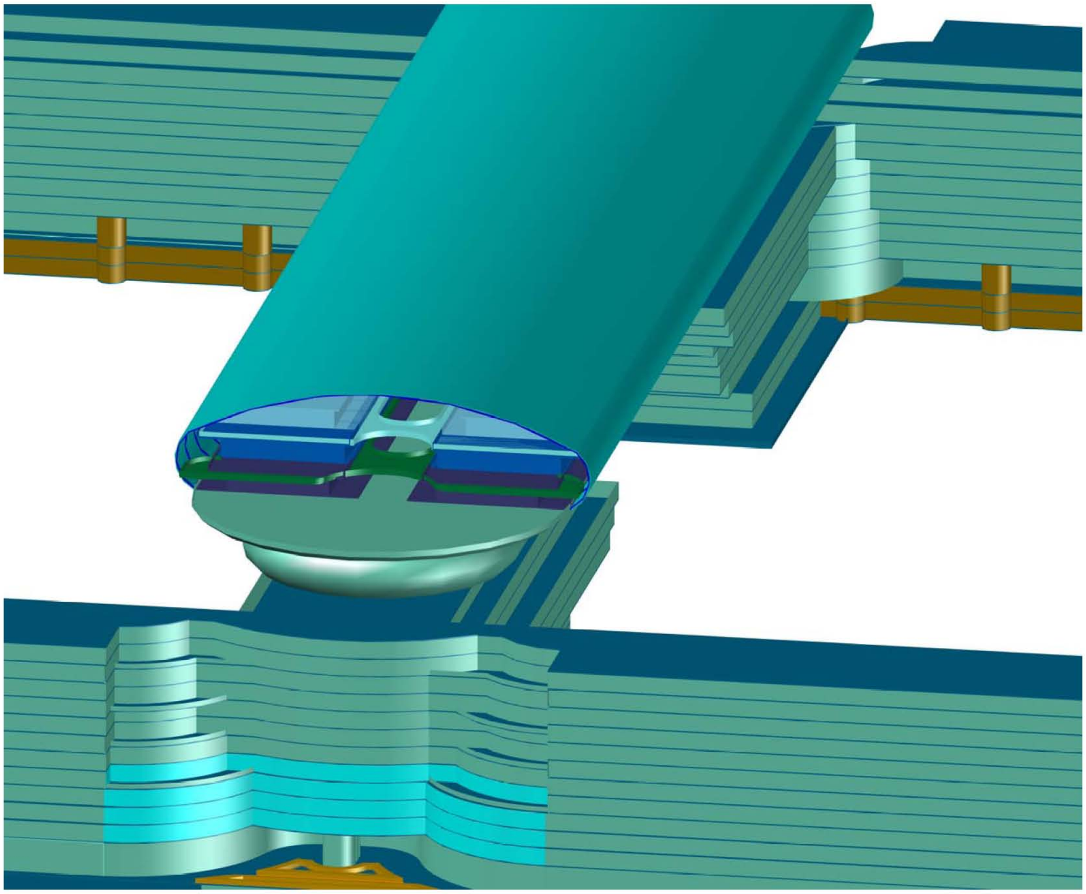


Figure No. 53 MeLing view high above bridge level from central business district

In figure 52 and 53 we can see the open recreation area as well as the open floor area within the structure to give a sense of a street below and allow for air circulation as well as day lighting to penetrate to the center of the community. We can also see the vaulted translucent photo voltaic roof which provides some of the electrical power needed by the bridge community.

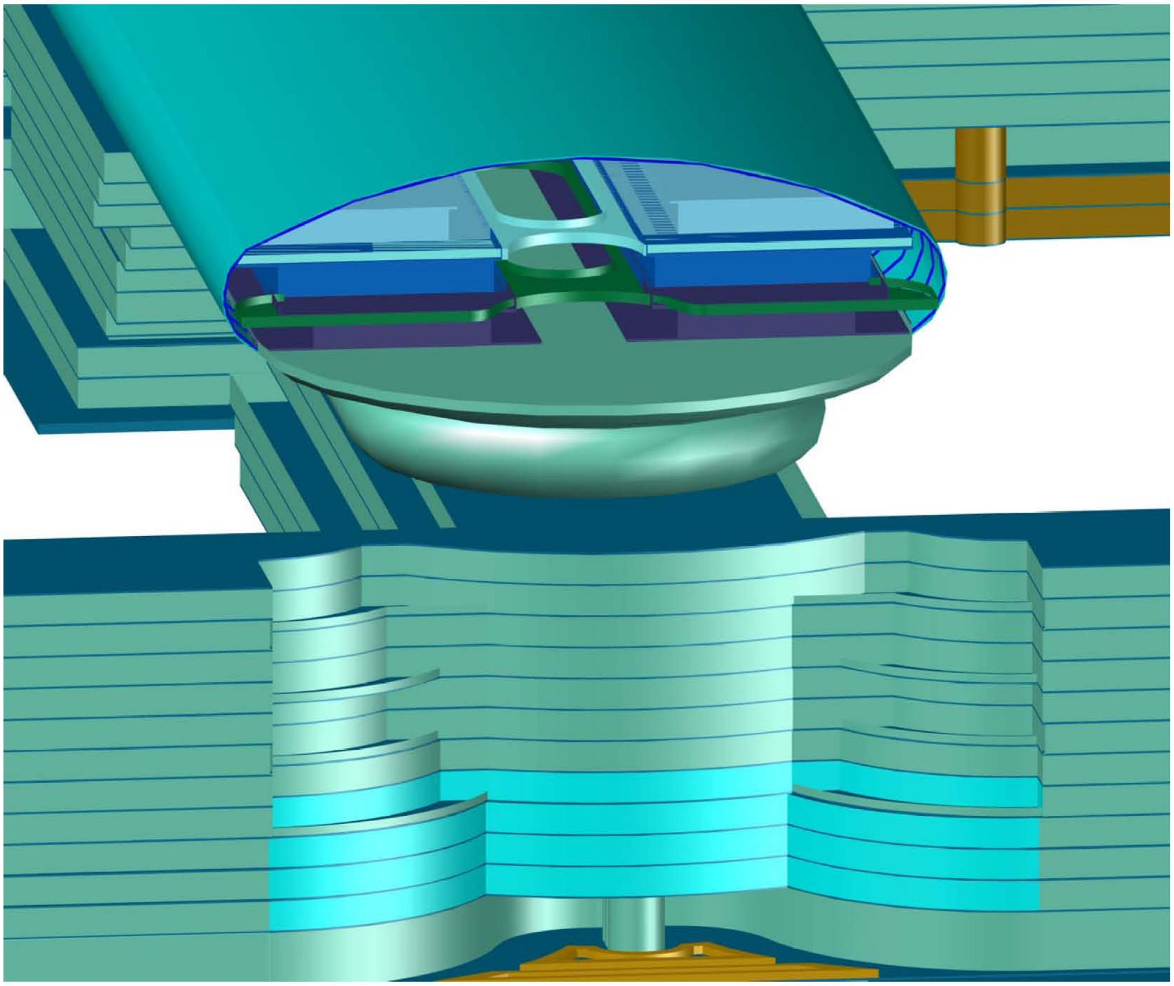


Figure No. 54 MeLing view high above bridge level from across street

In figure 54 above we have a better sense of the floor openings within the bridge with crosswalks for interior circulation for people to move about within the structure. We can also see the open spaces (walk ways) on the outside of the apartments. The rib structure can also be seen as dark blue tubes against the light blue photovoltaic roof shell.

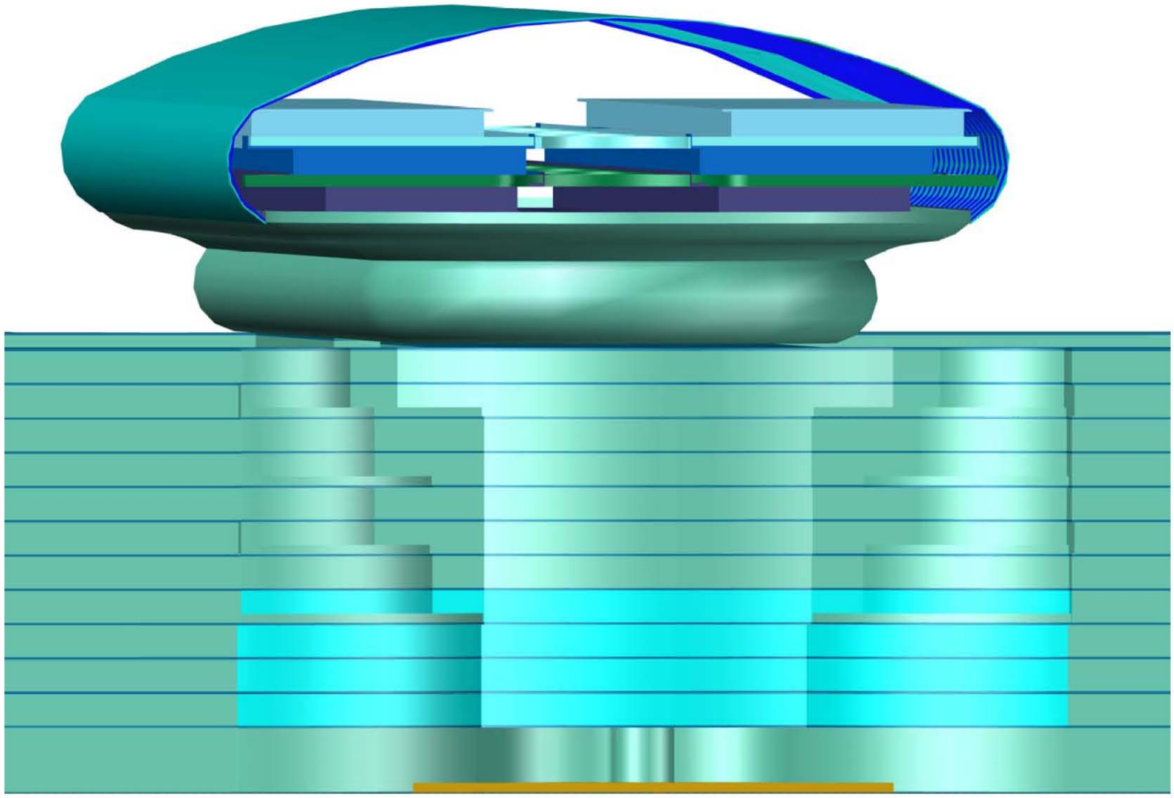


Figure No. 55 MeLing view of bridge level from across street

Figure 55 shows us what the neighbors across the street on the tenth floor would see as they look across the street. The street here is one hundred meter diameter traffic round about. There is an additional fifteen meters from the roundabout to the face of the twenty story office structure. This allows the scale of the traffic circle and the neighborhood to remain constant.

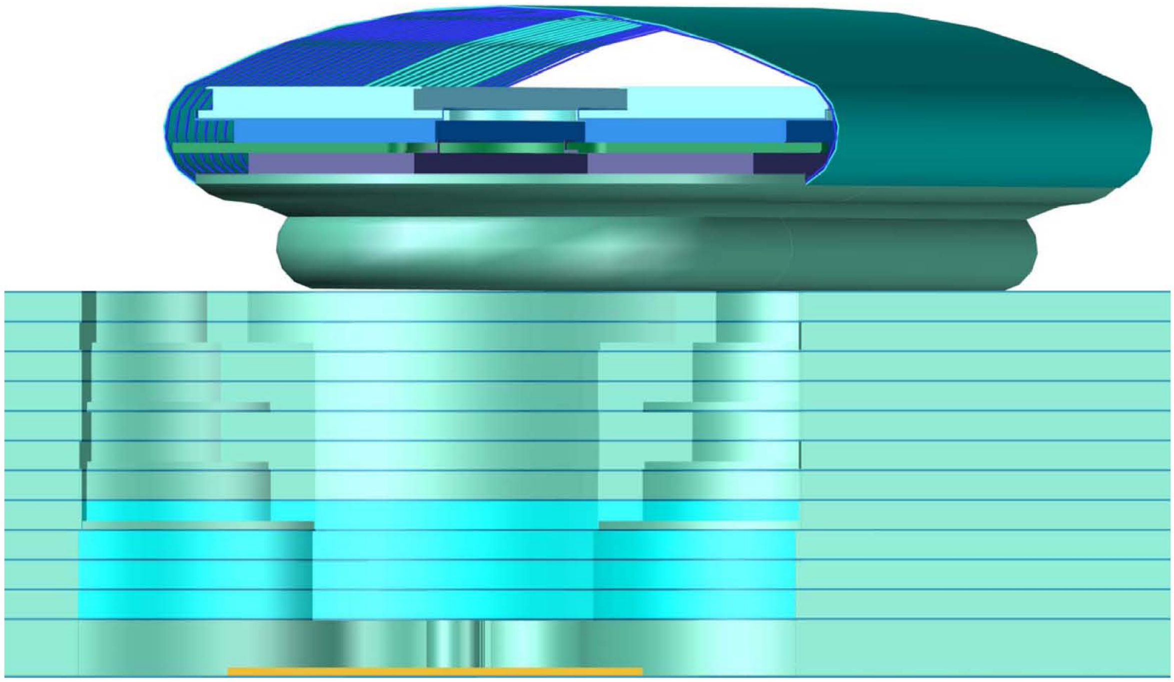


Figure No. 56 MeLing view of bridge level from central business district

Here figure 56 shows what would be seen from the street level from the other side of the roundabout heading towards the central business district where the cities major market (the Vietnamese traditional version of our shopping mall) and government district is located.

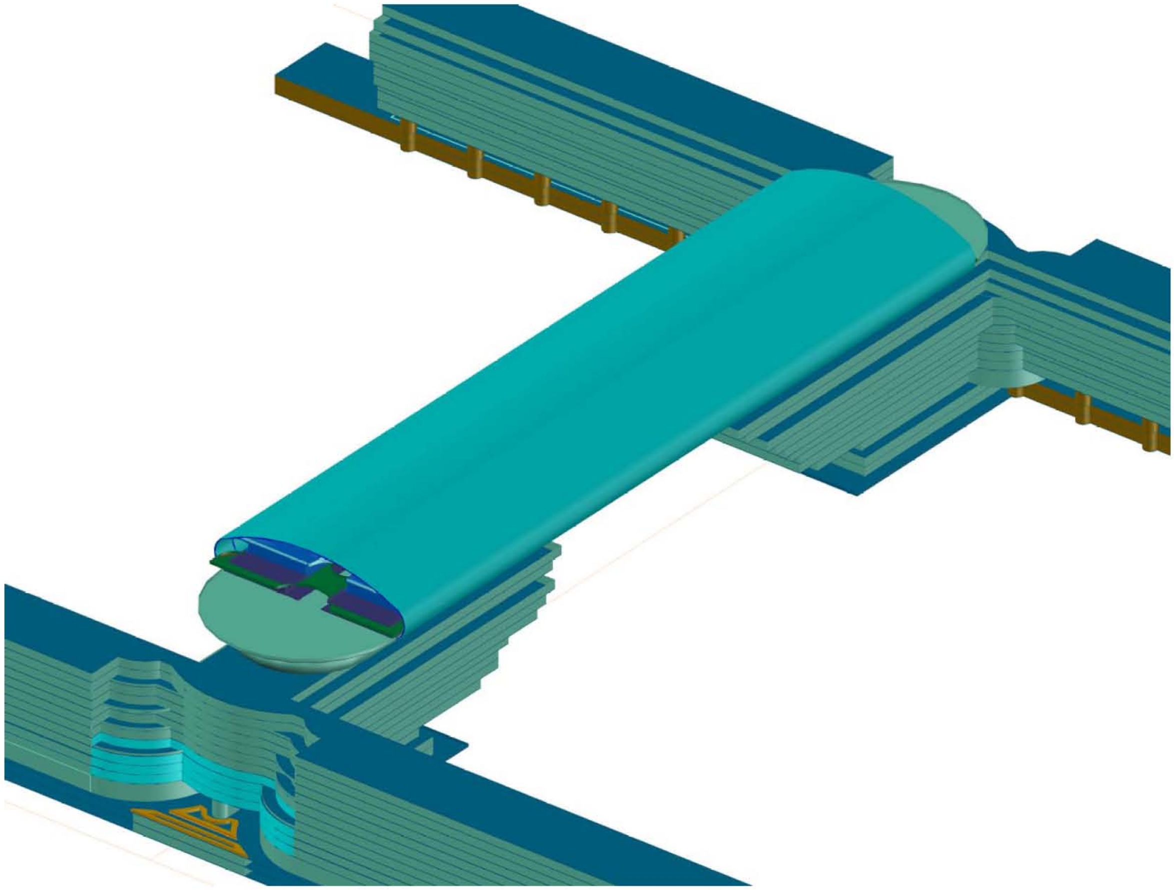


Figure No. 57 Aerial view of bridge from central business district

Figure 57 is a view of the prototype community as it would be seen from Saigon Center the highest (25 floors high) office building some four kilometers south of the new structure.

Here we can see the corbelled floor pattern which provides the required height clearance for ship passage as well as providing for a cantilevered frame to support the bridge as well as the housing above.

Part VI: Conclusion

“Steel – ACM’s – Reinforced Concrete”

Having read, perused, scanned, browsed, re-read, and whatever other term can be used for researching the subject of ACM’s I have come to several conclusions. I will not try to number them but I will go through and note some of them here.

For many years “steel” has obtained acceptance in the construction industry. This acceptance has been primarily in building large buildings or bridges. The same can be said for “reinforced concrete”. These two materials competed against each other for many decades and will compete for many more to come. However for residential construction they have been somewhat out of the game in getting the work, with the exception of large structures used as residential condominiums and apartments.

To a great degree “steel” has finally come to receive acceptance in single family construction to the level of wood. I realize this may sound somewhat strange to say but, many builders have not accepted this material as a building unit until the late 20th century. Although Steel offers many benefits over wood, many builders still will not build homes made of this material. Except for home foundations the same could be said about “concrete”, although concrete is much more difficult to work with when it comes to walls and raised floors.

Both of these materials have a minimum size commodity or break-even point whereas wood has a very low almost negligible base. There is a size and cost threshold for these two materials that wood does not have to be concerned about. In recent years light-gauge steel has finally broken this threshold, some forms of concrete have started to break this gap. Cement Masonry Units (CMU) has become more readily accepted but still not to the extent of which light-gauge steel or wood is used.

The “new materials” (ACM’s) are starting to break through this cost and availability barrier. They have successfully accomplished this within the sporting goods industry the automotive and sport boating industry as well as the aerospace industry: however in the typical construction industry which we are concerned it has a long way to go.

The petrol-chemical industry has accepted ACM's as a viable material because of their resistance to corrosion and its light weight characteristics which allows for quick and easy retrofit of their current facilities which constantly need repair and upgrade. ACM's can be shaped and configured to whatever shape needed and because of its high strength to weight ratio Fig. 54 below it is very convenient for the petro-chemical industry to quickly acquire the needed shapes, sizes and quantity.

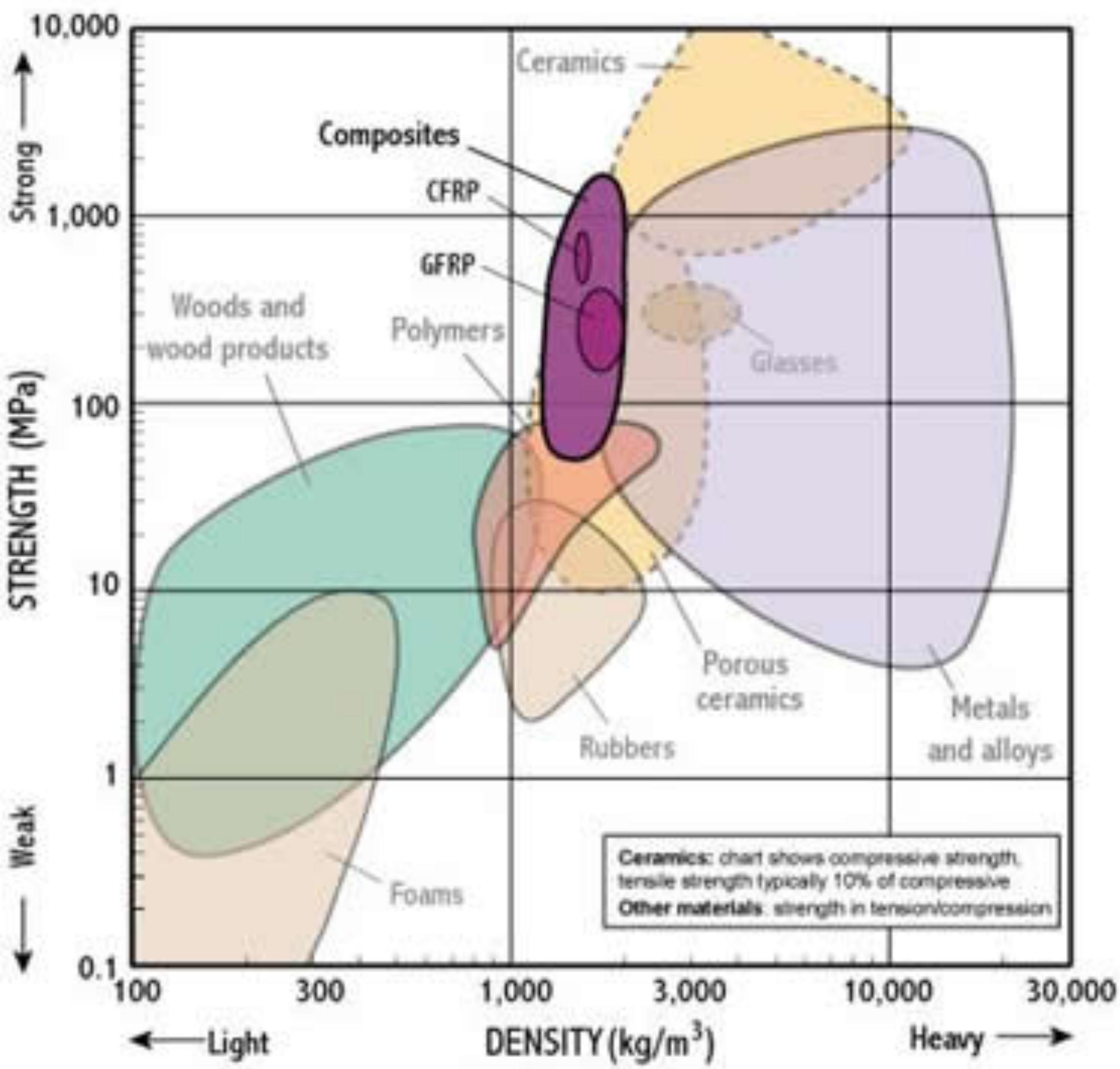


Figure No. 54 SP Systems Materials strength to weight ratio

Both the automotive and aerospace industry have completely accepted the use of ACM's as the material provides and satisfies their major needs, light weight and strength with the added convenience of been able to be used as a repairing system and limitless adaptation to whatever shape the product needs to be configured into. ACM's can be shaped, painted, configured and placed in just about any environment one can think of.

From my Architectural standpoint I have found that ACM's can be shaped woven into various structural shapes needed for construction, I Beams, angles, and tubes as seen in Fig. 55.

Figure No. 55. Biteam Composite Corp.

The availability of these materials been woven in to shape and strength needed and still be continuous to the required lengths provides the ability to obtain spans which will make the design more pleasing and functional.
Another observation of this material is that the manufacturing facility of the shapes can be established on site, the raw materials are easily brought in with smaller less expensive equipment and configured into the required shapes needed for construction. All of the required machinery and equipment needed for fabricating ACM's are readily available and are easy to transport or relocated on or to a new site location. In addition to all of this the required technical expertise needed can be easily learned by anyone with a minimal level of education. The engineer can configure the materials to whatever strength needed for the structural element required on the project.

For some time now Civil and Transportation Engineers have been using ACM's to build and strengthen bridge overpasses quite successfully fig. 56. Girders, beams and decks are made of a combination of fabrics so as to provide the strength and environmental conditions of the area to be installed in.

Figure No. 56. Composite bridge section
Lockheed – Martin Corporation

The concrete is also is also glass fiber reinforced which provides additional strength and with glass reinforcing rods which replaces the steel rods provides the resistance to corrosion due to salts and chemicals on roadways during cold winter months.

As can be seen in fig. 57 various types of composite tapes are combined to reinforce existing concrete bridge columns due to cracking or heavy sapling due to weather conditions, this is done in order to provide the required strength to keep the bridge in service until permanent repairs can be made.

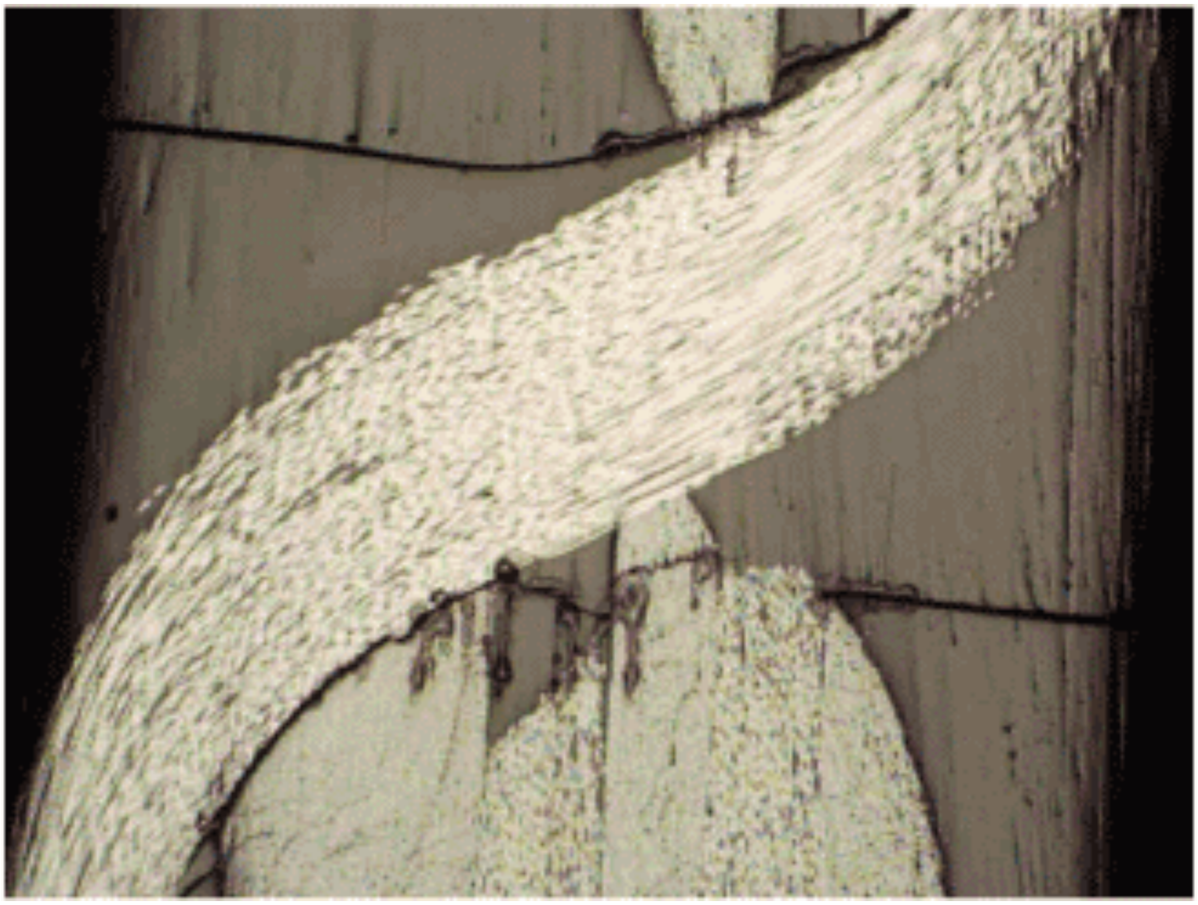


Figure No. 57 Advanced Composite Group, www.advanced-composite.com
Carbon fiber tape applied to reinforce a highway bridge overpass column.

These materials are currently available it is just a matter of acceptance. Many products and materials are not used simply because of the lack of knowledge by most users and governing agencies.

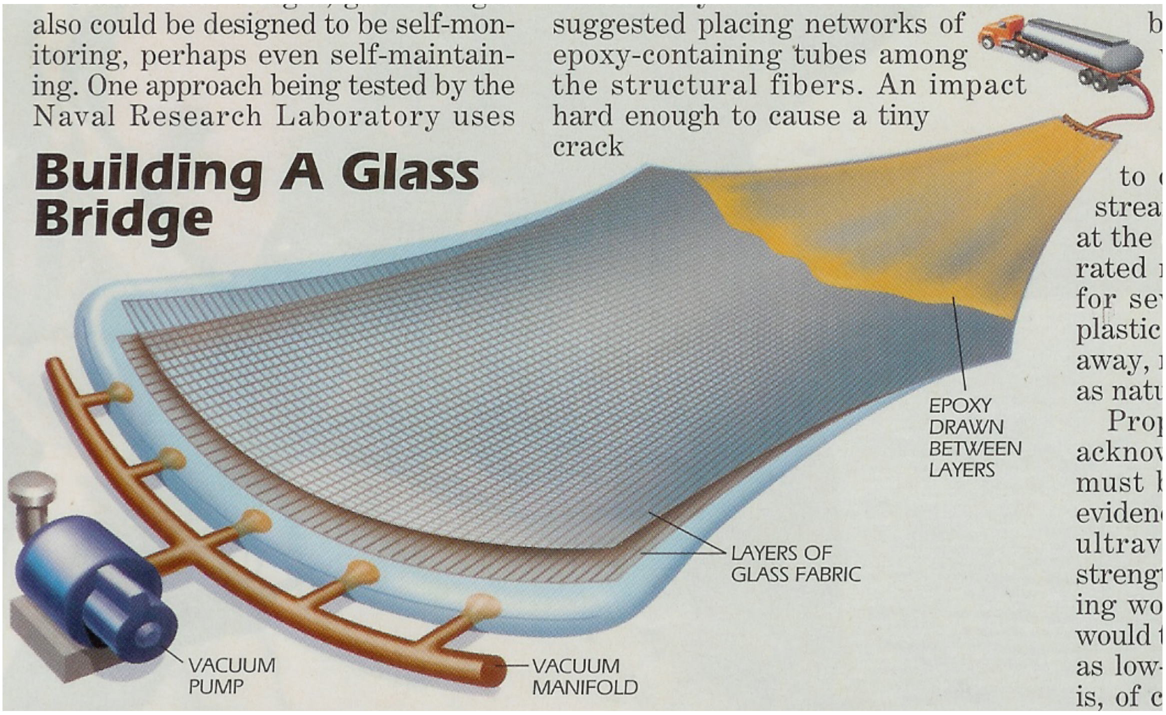


Figure No. 58 Popular Mechanic December 1997

Imagine creating a bridge "off site" Fig. 58 (the basic deck been made) and once it is completed it is moved to the location needing the bridge and placing it on site without any major interruption of services to the neighborhood it will serve Fig. 59.

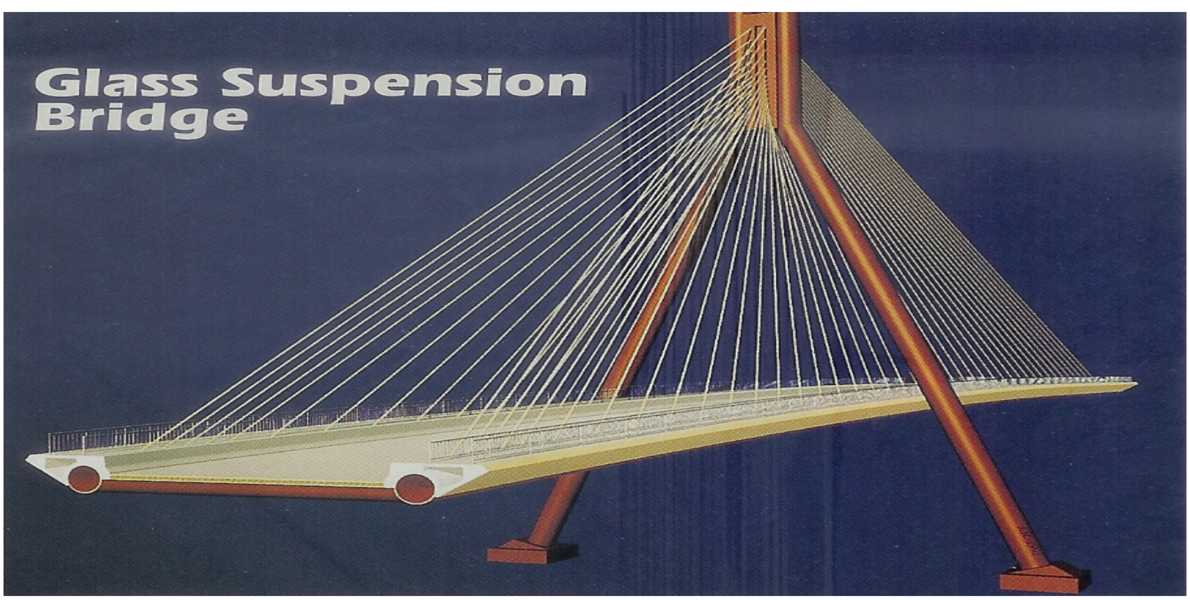


Figure No. 59. Popular Mechanic December 1997

As Architects and Engineers we know that new materials are created every day. I do not propose that we keep changing the materials we use in construction, but what I am saying is that we place more effort into convincing clients and government building officials to accept and use these more advanced materials. These types of products do not continue or last for very long if they do not fulfill the need they were created for or been adapted to.

Most ACM's Have the characteristic of dissipating heat very quickly. As yet it has not been conclusively proven that they all share this characteristic but I suspect that advanced composite materials do not retain heat as long as steel or concrete. This definitely helps in reducing the earth's heat retention. It has already been proven that areas with a great deal of paving and structures maintain higher ambient temperatures that areas with natural grass and soil.

As research on ACM's continues I will venture to say that more and more construction components will become available for architectural construction as shown on fig. 60

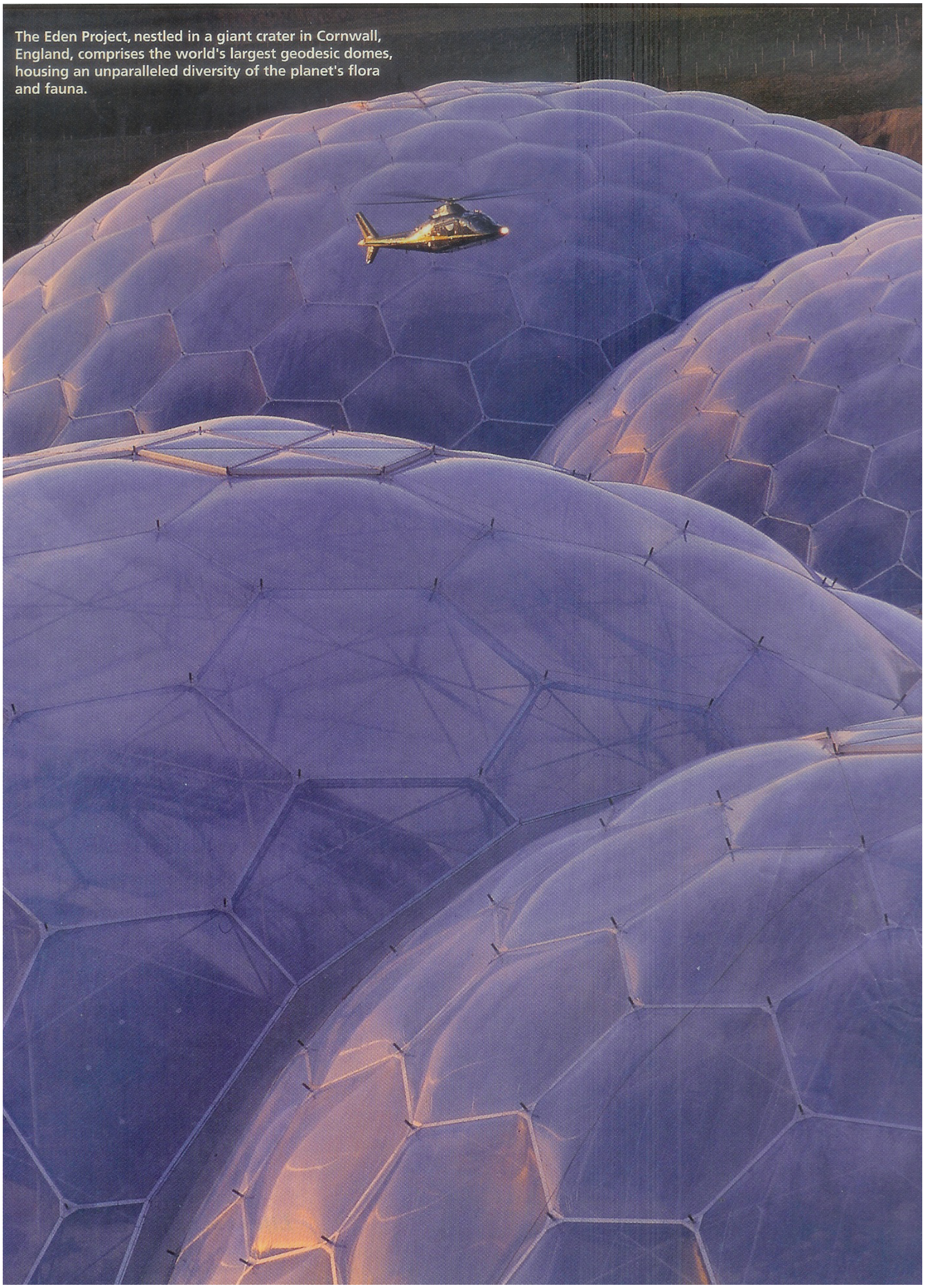


Figure No. 60 Popular Mechanic December 1997
The Eden Project, Cornwall, Englan

VII: Bibliography

Bibliography

ARHITECTURE

Allen, Edward, *Fundamentals of Building Construction Materials & Method*
John Wiley & Sons, N.Y. ISBN 0-471-18349-0

Browne, *Lionel Bridges – Masterpieces of Architecture*
Smithmark Publishers, New York, New York 1996 ISBN 0-7651-9942-4

Calthorpe, Peter; *The Next American Metropolis*
Prentice-Hall, Inc. Englewood Cliffs, New Jersey 1997 ISBN 1-8782-7168-7

Creswell, John W., *Research Design – Qualitative, Quantitative, & Mixed Method Approaches*,
Sage Publishing, Thousand Oaks, California, 2003 ISBN 0-7619-2442-6

Fletcher, Sir Banister, *A History of Architecture on the Comparative Method*
Charles Scribner & Sons, N.Y.

Franck, Karen A; Schneekloth, Lynda H. *Ordering Space (Types in Architecture and Design)*
John Wiley & Sons, New York 1994, ISBN 0-4712-8505-6

Groat, Linda; Wang, David; *Architectural Research Methods*
John Wiley & Sons, New York 2002, ISBN 0-471-33365-4

Mumford, Lewis; *The City in History*
Harvest Books, Orlando, Florida, 1961 ISBN 0-1561-8035-9

Neutra, Richard, J.; *Survival Through Design*
Oxford University Press, New York, New York, 1969 ISBN 0-1950-0790-5

So, Frank S.; Stollman, Israel; Beal, Frank; Arnold, David S.;
The Practice of Local Government Planning
International City Management Association, Washington D.C. 1980 ISBN 0-87326-021-1

Sandstrom, Gosta E, *Man the Builder*
McGraw Hill Book Company N.Y. Library of Congress 78-97121

Snyder, James C., *Architectural Research*
Van Nostrand Reinhold Company, New York, New York1997, ISBN 0-4422-8211-7

ENVIRONMENT

Barton, Hugh; Sustainable Communities – *The Potential for Eco-Neighborhoods*
Earthscan Publications Ltd., London, England 2000 ISBN 1-85383-513-7

Beatley, Thimothy; Manning, Kristy; *The Ecology of Place*
Island Press, Washington D.C. 1997 ISBN 1-55963-478-2

Ford, Andrew; *Modeling the Environment*
Island Press, Washington D.C. 1999 ISBN 1-55963-601-7

Kilbert, Charles J.; *Reshaping the Built Environment - Ecology, Ethics, and Economics*
Island Press, Washington D.C. 1999 ISBN 1-55963-702-1

Klosterman, Richard E.; *Community Analysis and Planning Techniques*
Rowman & Littlefield Publishers, Inc. 1990 ISBN 0-8476-3951-7

IEA/Novem ET All; *Photo-voltaics in the Built Environment (Architectural Ideas Competition)*

Walter, Bob; Arkin, Lois; Crenshaw, Richard; *Sustainable Cities, Concepts & Strategies for Eco-Dev.*
Eco-Home Media, Los Angeles, California 1993 ISBN 0-9633511-0-9

Bassin, Milton G.; Brodsky, Stanley M.; Wolkoff, Harold; *Statics and Strength of Materials*
McGraw-Hill, New York, New York 1997 ISBN 0-07-004023-0

Bassin, Milton G.; Brodsky, Stanley M. Wolkoff, Harold; *Statics and Strength of Materials*
Prentice-Hall, Inc. Englewood Cliffs, New Jersey 1988 ISBN 0-13-844655-5

Benjamin, B. S.; *Statics, Strengths and Structures for Architects*
Ashnorjen Bezaleel Publishing, Lawrence, Kansas, 1991, ISBN 0-942387-70-4

Burns, Thomas; *Applied Statics and Strength of Materials*
Delmar Publishers, Albany, New York 1997 ISBN 0-8273-6959-X

Cheng, Fa-Hwa; *Statics and Strength of Materials*
McGraw-Hill, New York, New York 1997 ISBN 0-02-803067-2

Das, Braja M., Hassler, Paul C.; *Statics and Mechanics of Materials*
Prentice-Hall, Englewood Cliffs, New Jersey, 1988, ISBN 0-13-844655-5

Diekmann, Edward F.; Razzano, Raymond A.; *Structural Engineering Syllabus*
East Bay Chapter, American Institute of Architects, Oakland, California 1981

Hibbeler, R. C.; *Structural Analysis*
Prentice-Hall International, Inc. Upper Saddle River, New Jersey 1995 ISBN 0-13-617671-2

Parker, Harry: Ambrose, James: *Simplified Engineering for Architects and Builders*

John Wiley & Sons, New York, 1993, ISBN 0-471-58703-6

Lin, T. Y.; Stotesbury, S. D.; *Structural Concepts and Systems for Architects and Engineers*
John Wiley & Sons, New York, New York 1981 ISBN 0-471-05186-1

Walmer, Maurice E.; Baron, Stephen L.; *Manual of Structural Design for Engineering Solutions*
Prentice-Hall, Inc. Englewood Cliffs, New Jersey 1972 ISBN 0-13-554352-5

Wendel, Wendel R.; Spaceframe *Basics, Handbook for Spaceframe Design and Engineering*
Space Structures International Corporation, Plainview, New York 1983

Michael Quinn Patton, *Qualitative Research & Evaluation Methods*
Sage Publications, London, 2002, ISBN 0-7619-1971-6

Roddewig, Richard J., Shlaes, Jared: *Analyzing the Economic Feasibility of a Development Project*
Amer Planning Assn. 1983, ISBN 9-9969-3601-5

Barbero, Ever J. *Introduction to Composite Materials Design*
Taylor and Francis Group, New York, New York ISBN 1-56032-701-4

Christensen, Richard M. *Mechanics of Composite Materials*
Dover Publications, Inc., Mineola, New York, 1979, 2005 ISBN 0-486-44239-X

Fiberline Et All; *Fiberline Design Manual*

Gay, Daniel; Hoa, Suong V.; Tsai, Stephen W.; *Composite Materials Design and Applications*
CRC Press, New York, New York 2003 ISBN 1-58716-084-6

Gutowski, Timothy G.; *Advanced Composites Manufacturing*
John Wiley & Sons, New York, New York 1997 ISBN 0-471-15301-X

K. Chawla K.; *Composite Materials Science & Engineering*
Springer-Verlag, New York, New York; 1987 ISBN 0-387-96478-9

Kaw, Autar K. *Mechanics of Composite Materials*
CRC Press, Taylor & Francis Group, Boca Raton, Florida 2006 ISBN: 0-8493-1343-0

Marshall, Andrew C.; *Composite Basics – 5*
Marshal Publishing, Walnut Creek Ca., 1998 ISBN 0-9664540-0-6

Mazumdar, Sanjay K. Ph.D. Composites Manufacturing *Materials, Product, and Process Engineering,*
CRC Press, Boca Ratan, London, New York, Washington D.C. 1999, ISBN 0-8493-0585-3

Morena, John J.; *Advanced Composite Mold Making*
Krieger Publishing Company; Malabar, Florida 1994 ISBN 0-89464-825-X

Schwartz, Mel; *Composite Materials Handbook*
McGraw-Hill, Inc.; New York, New York; 1992 ISBN 0-07-055819-1

Sierakowski, R. L.: Newaz, G. M.; *Damage Tolerance in Advanced Composites*
Technomic Publishing Co. Inc.; Lancaster, Pennsylvania; 1995 ISBN 1-56676-261-8

Swanson, Stephen R.; *Introduction to Design Analysis with Advanced Composite Materials*
Prentice-Hall, Inc. Upper Saddle River, New Jersey, 1997 ISBN 0-02-418554-X

Tsai, Stephen W.; Hahn, H. Thomas; *Introduction to Composite Materials*
Technomic Publishing Co. Inc.; Lancaster, Pennsylvania; 1980 ISBN 0-87762-2884

Verette, R. M., Labor, J. D., *Structural Criteria for Advanced Composites*
Northrop Corporation Aircraft Division, (For U.S. Air Force) 1974 NOR 74-272

Weeton, John W.; Peters, Dean M.; Thomas, Karyn L.; *Engineers Guide to Composite Materials*
American Society for Metals; Metals Park, Ohio 1987 ISBN 0-87170-226-6

AeroVac

Resin Infusion Manufacturers

Aero Space Composite Products

Composite Materials Suppliers

Society for the Advancement of Materials & Process Engineers (SAMPE)

Professional Association

SP Systems (UK)

Manufacturers & Suppliers

Emerging Construction Technologies (Purdue University)

Research Association

Biteam (Sweden)

Research & Development Consultants

SEECOM (UK)

Research & Development Consultants

US Air Force Research Laboratories

Research & Development Consultants

FiberGlast Development Corporation

Manufacturers & Suppliers

Renaissance Aeronautics Associates Inc.

INTERNET (WWW) PAGES

http://www.google.com

Composite Materials

http://www.MSN.com

Carbon Fiber Reinforced Materials

http://www.wtec.org/loyola/nano/toc.htm

Nanostructures Science and Technology

http://www.ml.afrl.mil

Advancements in Carbon nanofibers

http://trcs.he.uk.edu/textile/nonwovens/carbon.html

Carbon Fibers

http://whyfiles.org/145composite_materials/4.html

Composite Compositions

http://www.fiberglast.com

Fiberglass Composite Materials

Kevlar & Carbon Fiber

Sandwich Core Materials

Materials Fabric Specifications

Epoxy Resins and Resin Specifications

Mold Building Materials

http://www.geocities.com/Cape Canaveral/1320/

Carbon Fiber

http://www.sample.org

Carbon Fiber Research Organization

http://www.acp-composite/acp-ucfl.htm

Uni-carbon fiber laminates

http://csmweb2.emcweb.com/durable/1998/03/26feat/scitech.4.html

Electronic Properties of Carbon Fiber open field
To 'Smart' Structures

http://carbonfiber.conoco.com/news/010600.asp

Lower-Cost Carbon Fiber

http://www.new-technologies.org/ECT/Civil/cfrp.htm

Emerging Construction Technologies

http://www.epxbikes.com/epx/technology.asp

EXP Carbon Fiber Technology

http://www.seecom.org.uk/education.asp?sequence=36to84

Carbon Fiber Materials Specifications

http://www.seecom.org.uk/links.asp

On-line Composite Resources

http://www.icpress.co.uk/books/nanosci/p080.html

Physical Properties of Carbon Nanotubes

http://www.phys.ttu.edu/~tlmde/thesis/CARBON_NANOTUBES.html

Carbon Nanotubes

http://www.eurekalert.org/pub_releases/2002-04/ru-rry040502.php

Rice research… 'Designer' carbon nanotubes

http://www.business2.com/articles/mag/0,1640,42932,00.html

Just two Words: Carbon Nanotubes

http://www.ncnr.nist.gov/staff/taner/nanotube/exohydrogen.html

Exohydrogenated Single-Wall Carbon Nanotubes

http://imtsg7.epfl.ch/projects/topnano/

Nanomanipulation of Carbon Nanotubes

http://www.nature.com/nsu/991202/991201-1.html

Focus on Carbon nanotubes

http://www.princeton.edu/~cargroup/new_ver1/nanopage.html

Nanotubes

http://www.spacedaily.com/news/carbon-02c.html

Carbon nanotubes Grow Up in 3D

Nanotube 'Peapods' Have Tunable Elect. Prop.

http://www.cem.msu.edu/~cem181fp/nanotube/mozillaabstrct.htm

Carbon Nanotube

http://www.cem.msu.edu/~cem181h/glossary.htm

CEM-181H Glossary of Chemical Terminology

http://www.research.ibm.com./nanoschience/manipulation.htm

Nanotube Manipulation

http://www.3rdtech.com/carbon_nanotubes.htm

Carbon Nanotube

http://www.ruf.rice.edu/~smalleyg/Papers/ropes.htm

Crystalline Ropes of Metallic Carbon Nanotubes

http://www.science.nasa.gov/~deepak/home.html

Molecular Dynamics

http://www.space.com/businesstechnology/technology/nanotube_co...

Nanotubes Light Weight, Superstrong

http://www.nanoledge.com/english/introduction.html

Short Carbon nanotubes Introduction

http://www.botany.utexas.edu/facstaff/facpages/mbrown/ongress/tspir...

Hi-Res TEM Observations of Carbon nanotubes

VII: Appendix

Acronyms

(These acronyms have been accumulated from various readings for clarification of study)

ABS Acrylonitrile-butadiene-styrene

ACCEM Advanced Composite Cost Estimating Model

ACM Advanced Composite Material

ASME American Society Mechanical Engineers

ASTM American Standards Testing Materials

ATL Automated Tape Layup

ATP Automated Toe Placement

B-Al Boron-Aluminum Composite

B-Ep Boron-epoxy

BMC Bulk-molding Compound

BMI Bismaleimides

BML Bilk-molding Compound

B-Pi Boron-Polyimide

C-Ep Carbon Epoxy

C-Gr Carbon-graphite

CTV

Cu-Gr Copper Graphite Composite

CVD Chemical Vapor Deposition

DS Directionally Solidified Euthectics

EGl-Ep E-Glass Epoxy

EMC Elastomeric-molding Compound

ERM Elastic-reservoir Molding

FP Polycrystalline Alumina Fiber

FRP Fiber -reinforced Polymer

GRP Glass Reinforced Plastic

Gr-Ep Graphite Epoxy

IML Inner Mold Line

LCM Liquid Composite

LHS Low-cost High-strength

MWKs Multi-axial Warp Knits

MMC Metal-matrix Composite

OML Outer Mold Line

PAN Polyacrylonitrile

PBT Poly-butylene Terephthalate

PEEK Polyether Ether Ketone

PES Polyethersulfone

PET Polyethylene Terephthalate

PPS Polyphenylene Sulfide

PS Polysulfone Epoxy

RRIM Resin Reaction Injection Molding

RTM Resin Transfer Molding

SMC Sheet-molding Compound

SPMC Solid Polyester Molding Compound

SRIM Solidification Resin Injection Molding

TERTM Thermal Expansion Resin Transfer Molding

UDC Unidirectional Composite

UMC Unidirectional Molding Compound

URTRI Ultimately Reinforced Thermoset Reinforcing Injection

VARI Vacuum-assisted Resin Injection

XMC Directionally Reinforced Molding Compound

GLOSSARY

(These definitions have been accumulated from various readings for clarification of study)

A

A4 Grade classification for stainless steel, acid-proof bolts, nuts and discs

Acetone A keytone group solvent that is used to dissolve polyester resins. Used to a large extent in the cleanup of tools in fiberglass operations.

Accelerator A chemical additive that hastens curing or chemical reaction (see also catalyst)

Additive An ingredient mixed into resin to improve properties. Examples include plasticizers, and flame retardant.

Adhesive Glue that costs more than 20 cents ($0.20) per pound. A substance applied to matting surfaces to bond them by surface attachment. An adhesive can be liquid, film or in a paste form.

Adhered The pieces that you bond together.

Adhesive Film A thin plastic film onto which premixed adhesives are cast.

Advanced composite That group of materials usually associated with military or commercial aerospace structures using the newer materials. These materials usually consist of a resin matrix-typically an epoxy, polycyanate, polyester, or vinyl ester-and fiber reinforcement.

Alligatoring A visible cosmetic defect in the exposed gel coat which look like wrinkles or alligator skin.

Anaerobic adhesive Expensive adhesives that cure initially as a result of being confined within the bond line in the absence of air.

Anisotropic Fiber directionality in which different properties are exhibited when tested along axes of different directions.

Aramid A high-strength, high-stiffness aromatic polyamide fiber.

Autoclave A pressure vessel into which a vacuum bagged part is so that the part is made to see not just the 15 or so psi that the vacuum provides, but up to as much as 500 psi more.

B

B-Staged bonding film Adhesives finished as a dry film, comes in a roll, and costs from $.50 to $2.00 per square foot or more.

Basket weave Uses two yarns next to each other, in place of a single yarn, to make a plain weave.

Barcol Hardness A surface hardness value obtained by measuring the penetration resistance of a given material to a sharp steel point under a spring load. Barcol impressor is an instrument that measures the hardness on a 0-100 scale in accordance to ASTM D-2583.

Barrier cream A cream used to protect the skin from contact with resin.

Benzoyl Peroxide (BPO) An initiator for curing polyester resin. BPO is used with aniline accelerators or where heat is used to cure the resin.

Binder A resin soluble adhesive that secures the random fibers in chopped strand mat or continuous strand roving.

Bidirectional Laminate A laminate with fibers oriented in more than one direction on the same plane.

Bleeder material Same as the breather ply but used in much greater quantities so that it can soak up the excess resin as it comes through the perforated release ply or tear ply.

Blister A flaw either between layers of laminate or between the gel coat film and laminate.

Bonding fixture A device used to position exactly the adherent's so that bushing, hinge line, actuator points and other such items will be in the right place after the glue hardens. Also called a bonding tool or jig.

Breakout Separation or breakage of fibers when the edges of a composite part are drilled or cut.

Breather ply Any disposable fabric used in quantity so that the air can freely pass through the surface of the entire part inside 'the vacuum bag'.

Bromine A fire-retardant (halogen) used to reduce or eliminate a resin's tendency to burn.

C

Casting The process of pouring a mixture of resin, fillers and/or fibers into a mold as opposed to building up layers through lamination. This technique produces different physical properties from laminating.

Carbon Fiber Reinforcing fiber known for its lightweight, high strength and high stiffness. Fibers are produced by high temperature treatment of an organic precursor fiber based on PAN (polyarcrylonitrile), rayon or pitch in an inert atmosphere at temperatures above 1800^{o}F.

Catalyst A substance that promotes and/or controls curing of a compound without being consumed in the reaction.

Clean surface Something much cleaner than you would expect.

Cleanup Almost impossible to do after the cure if the adhesive is any good.

Centipoise A unit of measurement used to describe the viscosity of a liquid. Viscosity is measured with a Brookfield Viscometer for most polyester resin applications.

Chalking A surface phenomenon indicating the degradation of a cosmetic surface. Chalking is a powdery film which appears lighter than the original color.

Chopped mat strand A fiberglass reinforcement consisting of short strands of fiber arranged in a random pattern and held together with a binder. Matt is generally used in rolls consisting of ¾ oz /ft^2 material to 2 oz/ft^2 material.

Coefficient of thermal expansion (CTE) A materials fractional change in length for a given unit change of temperature.

Cohesion Adherence of a single substance to itself. Also, the property holding a single substance together.

Cohesive failure The matrix failed within itself, leaving adhesive on each adherent surface.

Composite A material that combines fiber and a bonding matrix to maximize specific performance properties. Neither element merges completely with the other.

Composite materials Any materials consisting of two or more identifiable materials deliberately combined to form a heterogeneous structure with desired or independent structure.

Compression mold A closed mold usually of steel, used to form a composite under heat and pressure.

Compression modulus A mechanical property description which measures the compression of a sample at a specific load. Described in ASTM D-695.

Compressive strength The capacity to resist a crushing or buckling force; the maximum compressive load a specimen sustains divided by its original cross sectional area.

Constituent An essential component or element needed to complete the make-up of composite i.e. the matrix, the carbon fiber, or other such elements.

Contact molding Refers to a single open mold onto which resin and reinforcement material can be applied. Contact molding is characterized by one finished cosmetic side.

Continuous filament strand A fiber bundle composed of many glass filaments. Also when referring to gun roving; a collection of string like glass fiber or yarn, which is fed through a chopper gun in the spray up process.

Continuous laminating An automated process for forming panels and sheeting in which fabric or mat is passed through a resin bath, brought together between covering sheets, and passed through a heating zone for cure. Squeeze rolls control thickness and resin content as the various piles are brought together.

Continuous mat A material formed from fibers of yarns with random fiber orientation.

Continuous strand roving A bundle of glass filaments which are fed through a chopper gun in the spray up process.

Core A low density material used between two FRP skins.

Crazing Cracking of gel coat or resin due to stress.

Creep The dimensional change in a material under physical load over time beyond instantaneous elastic deformation.

Cross-linking The chemical bonding of molecules which in polymers occurs in the curing transition from a liquid to a solid

Crowfoot One yarn crosses over three or four yarns.

Cure to irreversibly change the molecular structure and physical properties of a thermosetting resin by chemical reaction via heat and catalyst alone or in combination, with or without pressure.

Cure cycle The specific sequence of temperature, pressure and time used to cure a specific adhesive system.

Curing Agent or Hardener A catalyst or reactive agent brings about polymerization when added to a resin (see catalyst).

Cure Temperature The temperature at which a material attains final cure.

D

Damping Diminishing the intensity of vibration.

Delamination The separation of ply layers due to adhesive failure or the separation of layers of fabric from the core structure. A delamination may be associated with bridging, drilling and trimming.

Die, molding tool An assembly of parts containing the space from which the molding takes its form.

Dielectric strength The value of a material as an electrical insulator or resistance to the flow of electric current.

Draft The angle of the vertical components of a mold which allow the removal of the part.

E

Eccentricity moment Moment resulting from a force not acting upon the line of gravity.

E-glass (electrical glass) Borosilicate glass fibers possessing conductive properties; most often used in conventional polymer matrix composites.

Elastic limit The greatest stress a material is capable of sustaining without permanent strain remaining after complete release of the stress.

Elongation Standard measure for the amount a sample can stretch as a percentage of original length before it fails or breaks.

Environmentally sensitive Been aware and cognoscente of the natural condition of the site to be working in, and to minimally alter its condition from its natural state.

Epoxy resin A common thermoset material used as a bonding matrix to hold fibers together. When mixed with a catalyst, epoxy resins a resistant to chemicals and water and are unaffected by heat or cold.

Exothermic heath Internal heat developed and released during a chemical reaction or curing process.

F

Fatigue Failure of a material's mechanical properties caused by repeated stress over time.

Fatigue strength The maximum cyclical stress a material can withstand for a given number of cycles before it fails.

Fiber architecture The design of a fibrous part in which the fibers are arranged in a particular way to achieve the desired results. This may include braided, stitched or woven fabrics, mats, roving or carbon tows.

Fiber content/glass content The amount of fiber in a composite expressed as a ratio to the matrix.

Fiber glass Glass which has been extruded into extremely fine filament. The filaments vary in diameter, and are measured in microns. These filaments come in many forms such as roving, woven roving, mat and continuous strands.

Fiber reinforcement Fabric and components made of Glass, Kevlar©, Carbon fiber, Nextel©, Quartz, Boron, Spectra© fiber, or any number of other fibers all of which are very small in diameter and very strong, imparting a high degree of strength to the resulting mixture.

Fiber reinforced plastic A composite material or part that consists of a resin matrix containing reinforced fibers such as glass or carbon having greater strength or stiffness than the resin. The term GRP is most often used to denote glass fiber-reinforced plastic.

Filament A single thread like fiber of extruded glass. Typically microns in diameter.

Filament winding An automated process for fabricating composites in which continuous roving, either pre-impregnated with resin or drawn through a resin bath, is wound around a rotating mandrel.

Filler Material added to the mixed resin to increase viscosity, improve appearance and/or lower density and cost.

Finite element Analysis (FEA) A computer analysis technique using the finite element method, often used to model complex structures.

Flexural strength The strength of a material in bending expressed usually in terms of force per unit area, as stress of a bent test sample at the instant of failure.

Folding Defect due to bending/folding of fibers.

Formulated adhesive Adhesive made up of resins and hardeners, plus an infinite number of miscellaneous items, like mummy dust, diatomaceous earth, clay flocked fibers, aluminum powder, asbestos fibers, ground rubber, and a million other very important materials that remain secret.

Fish eye The effect of surface contamination which causes a circular separation of a paint or gel coat.

Flame retardant resin A polyester resin which has been specifically formulated to reduce the flame spread and/or smoke generation characteristics.

Flammability A measure of how fast a material will burn under controlled conditions. ASTM D-635/UL E-84 test.

Flexural modulus ASTM D-790. An engineering measurement which determines how much a sample will bend when a given load is applied.

G

Gel The irreversible point at which a polymer changes from a liquid to a semi-solid. Sometimes called the “B” stage.

Gel coat A surface coat of specialized polyester resin, either colored or clear, providing a cosmetic enhancement and weatherability to a laminate.

Gel time The length of time from catalyzation to gel or “B” stage.

Glass fiber Glass fibers are manufactured by “drawing” melted glass through nozzles. Due to its relative high strength, easy machining and low price, glass fiber is the most commonly used reinforcement for polymer-based composites.

Glue Any substance that sticks materials together with usable strength.

H

Halogenated resin A resin combined with chlorine or bromine to increase fire retardancy.

Heat distortion point The temperature at which the strength of a material begins to degrade.

Heat-distortion temperature (HDT) The temperature at which a test bar deflects a certain amount under specified temperature stated load.

Heat-acid resin Polyester resin with exceptional fire qualities.

Honeycomb A lightweight cellular structure made from either metallic sheet materials or non-metallic materials (e.g. resin impregnated paper or woven fabric) and formed into hexagonal nested cells.

Hybrid A fibrous product made with two or more types of reinforcing fibers, e.g. glass and carbon.

Hybrid composite A composite reinforced by hybrid.

Hybrid weave Woven fibrous product based on two or more materials.

Hydro-clave An autoclave that uses water instead of air or nitrogen as the working fluid. Using pressures of 1000 psi or higher, where a gas would be extremely dangerous.

I

Intumescent A fire-retardant technology which causes an otherwise flammable material to foam, forming an insulation barrier when exposed to heat.

Impact strength A material's ability to withstand shock loading; measured by the fracturing of a specimen.

Impregnated The saturation of the voids and interstices of reinforcement with a resin.

Interface The surface between two materials (in glass fibers, for instance, the area at which the glass and sizing meet; in a laminate, the area at which the laminating resin meet.)

Interlaminar Existing or occurring between two or more adjacent laminae.

Interlaminar shear A shear force that produces displacement between two laminae along the plane or their interface.

Isocyanate A high reactive monomer used in reaction injection molding (RIM).

Isophthalic A polyester resin based on Isophthalic acid, generally higher in properties than general purpose or orthothatic polyester resin.

Isotropic Fiber directionality, with uniform properties in all directions, independent of the direction of applied load.

J

Jackstraw A visual effect of glass fiber turning white in a cured laminate. Does not usually effect the strength of the material but could be an indication of materials incompatibility.

K

Kevlar A strong, lightweight Aramid fiber trademarked by DuPont and used as a reinforcement material.

L

Laminant A material composed of more layers of the same or different types of materials.

Laminate To unite layers with a bonding material, usually via pressure and heat.

Lap joint A joint made by overlapping two parts and bonding them together.

Leno weave An open weave pattern. The warp yarns are arranged in pairs, twisted or interlocking around the filling yarn to prevent slippage and make the open weave stronger and more firm.

Low pressure laminates Laminated, molded and cured using pressures from 400psi down to and including the pressure obtained by the mere contact of the plies.

Low profile Describes resin compounds formulated for low-to-zero shrinkage during molding.

M

Mat A fibrous reinforcing material composed of chopped filaments (for chopped-strand mat) or swirled filaments (for continuous-strand mat) with a binder applied to maintain form; available in blankets of various widths, weights, thickness and lengths.

Matrix The material in which the fiber reinforcements are embedded. Thermoplastic and thermoset resin systems, as well as metal and ceramic, or glass can be used.

Metal-matrix composites Materials in which continuous carbon, silicon carbide, or ceramic fibers are embedded in a metallic matrix material.

Mek Peroxide (MEKP) An initiator often referred to as a catalyst and used to initiate polymerization of a resin. Methyl Ethyl Ketone Peroxide.

Microballoons Microscopic bubbles of glass, ceramic or Phenolic, used as a filler or to create syntactic foam or putty mixture.

Micro-cracking Cracking in composites at points where thermal stresses exceed the strength of the matrix.

Mock leno weave An open mesh design that simulates a leno weave by interlacing and grouping the warp and weft yarns with spaces between the groups. Warp yarns are not interlaced in a true leno weave.

Modulus The physical measurement of stiffness in a material, equaling the ratio of applied load (stress) to the resultant deformation of the materials such s elasticity or sheer.

Modulus of Elasticity The ratio of normal stress to the corresponding strain for tensile or compressive stress less than the proportional limit of the material.

Moisture absorption A material assimilation of water vapor from air, as distinguished from water absorption by immersion, which results in weight gain.

Monomer A single molecule that can react with like or unlike molecules to form a polymer.

Mould release agent A lubricant used to prevent a part from sticking to a mould.

N

Non-destructive inspection (NDI) Determination of material or part characteristics without permanent alteration of the test subject. (Non-destructive testing (NDT) and non-destructive evaluation (NDE) are generally considered synonymous with (NDI).

Non-woven Chopped fibers held together with a resin-soluble sizing or binder, as well as continuous strand mat, and various unidirectional materials.

NPG gel coat Neopentyl glycol gel coat has enhanced weather ability compared to non-NPG gel coat.

O

Orange peel A gel coated or panted finish which is not smooth and is patterned similar to an orange's skin.

Orthophthalic or ortho resin A polyester resin based on Orthophthalic acid, also known as a general purpose resin (GP).

Orthotropic A materials tendency to grow or form along a vertical line under stress.

P

Peel ply Layers of material applied to a lay up surface that is removed from the cured laminate prior to bonding operations, leaving a clean, resin-rich surface ready for bonding.

Peel strength Strength of an adhesive bond obtained by stress that is applied "in a peeling mode"

Phenolic resin Thermosetting resin produced by condensation of an aromatic alcohol with an aldehyde, particularly phenol with formaldehyde.

Plain weave The most simple weave pattern, with each strand going alternately over and under crossing the strands.

Plastic Organic chemical compounds called polymers which can be formulated to produce a wide range of properties.

Poisson's ratio When a material is stretched, its cross sectional area changes as well as its length**.** Poisson's ratio is the ratio constant relating these changes in dimensions, and is defined as the ratio of the change in width to the change in length per unit length.

Polyester Thermosetting resins produced by dissolving unsaturated, generally linear, alkyd resins in a vinyl-type active monomer such as styrene. The resins are usually furnished in solution form, but powdered solids are also available.

Polymer A large molecule formed by combining many smaller molecules or monomers in a regular pattern.

Polyvinyl alcohol (PVA) A parting film applied to a mold for part releasing.

Postcure Additional elevated temperature cure, usually without pressure, to improve final properties and/or complete the cure. In certain resins, complete cure and ultimate mechanical properties are attained only by exposure of the cured resin to higher temperatures than those of curing.

Prepreg Reinforcing material impregnated with resin prior to the molding process and cured by the application of heat.

Print through A distortion in the surface of a part which allows the pattern of the core or reinforcement to be visible through the surface. Also known as print out, telegraphing, or read through.

Pultrusion / pultruding An automated, continuous process for manufacturing composite rods, tubes and structural shapes having a constant cross-section. Roving and other reinforcements are saturated with resin and continuously pulled through a heated die, where the part is formed and cured. The cured part is then cut to length.

Parolysis The decomposition or transformation of a compound caused by heat.

Q

Quasi-isotropic Approximating isotropy by orienting piles in several directions.

R

Reinforcement The key element added to a matrix to provide required properties (primarily, strength and stiffness); ranges from short fibers and continuous fibers through complex textile forms.

Resin A solid or pseudo-solid material with indefinite and often higher molecular weight and a softening or melting range that exhibits a tendency to flow when subjected to stress. (As composite matrices, resins bind together reinforcement fibers.)

Roving A very large yarn (initially fiberglass) with yarn structure depending on the amount, basic yarn strength, orientation and construction of the yarn used. A collection of bundles of continuous glass fiber filaments, either as untwisted strands or as twisted yarn.

S

Sandwich construction A laminate with two composite skins separated by, but bonded to, a structural core material. Used to create stiff, light weight structures.

S-Glass Magnesia / alumina / silicate glass reinforcement designed to provide very high tensile strength; commonly used in high-performance parts.

Satin weave One yarn crosses over four or more yarns.

Shear An action or stress resulting from applied forces that cause two continuous parts of a body to slide relative to each other.

Shear strength The maximum shear stress that a material is capable of sustaining.

Sizing A solution of chemical additives used to coat filaments. The additives protect the filaments from water absorption and abrasion; they also lubricate the filaments and reduce static electricity.

Specific gravity The ratio between the density of a given substance and the density of water.

Straight resin adhesive An adhesive made of only resin and hardener.

Stiffness A materials ability to resist bending; relationship of load to deformation for a particular material.

Stress Internal resistance to change in size or shape, expressed in force per unit area.

Stress concentration The magnification of applied stress in the region of a notch, void, hole or inclusion

Stress corrosion Preferential attack of areas under stress in a corrosive environment, that alone would not have caused corrosion.

Stress crack External or internal crack in a composite caused by tensile stresses: cracking may be present initially, externally or in combination.

Styrene monomer A component of polyester resin that provides crosslinking sites and reduces the polyester to a workable viscosity.

Surface gloss The typical shiny surface on a cured plastic or composite part that prevents the adhesive from sticking to the material.

Surfactant Chemicals used to modify or change the surface of a layer of resin or polymer. Usually used to form a film on a curing resin, producing a tack-free surface.

Surfacing veil Accompanies other reinforcing mats and fabrics to enhance the quality of the surface finish. Designed to block out the fiber patterns of the underlying reinforcements, it often adds ultraviolet protection to the surface.

Sustainability The ability of an entity to maintain its existence without overburdening its surrounding environment or creating a diminishing condition, thus reducing the natural self supporting existence of its neighboring entities.

Syntactic foam A foam made by mixing micro spheres with a resin

Synthetic fibers Fiber’s made of materials other than glass or carbon, such as polyester.

Synthetic resin adhesive An adhesive that costs more than $1.00 per pound.

T

Tensile load A dulling load applied to opposite ends of a given sample.

Tensile elongation An engineering term referring to the amount of stretch a sample experiences during tensile strain. ASTM D-638.

Tensile strength The maximum stress sustained by a composite specimen before it fails in a tensile test.

Thermal coefficient of expansion Measures dimensional changes of a material when heated or cooled. Measured in inches per inch per degree.

Thermoplastic A composite matrix capable of being repeatedly softened by an increase in temperature and hardened by a decrease in temperature.

Thermoset Composite matrix cured by heat and pressure or with a catalyst into an infusible and insoluble material. Once cured, a thermoset cannot be returned to the uncured state.

Thermoset system The matrix, the thermoset and the additive required to manufacture the end product by the chosen production method.

Thixotropic A term describing the rehology (or flow [viscosity] characteristics) of a liquid that resists flowing or drainage during application.

Thixotropic index (T.I.) A measure of thixotropy using a Brookfield Viscometer. (The low speed viscosity divided by the high speed viscosity).

Tool Another term for die or mould.

Twill weave One yarn crosses over two yarns.

U

Unidirectional (UD) Orientation of fibers in the same direction, as in unidirectional fabric, tape or laminate.

UV stabilizer A chemical compound which improves resistance to degradation from ultraviolet radiation.

V

Voids Pockets of entrapped gas that have been cured into a laminate.

Vinyl esters A class of thermosetting resins containing ester of acrylic and or methacrylic acids.

Viscosity The tendency of a material to resist flow. As temperature increases, the viscosity of most materials decreases.

Volatile organic compound (VOCs) Chemical substances, such as solvents, that readily evaporates or volatilize into the air.

W

Water absorption The ratio of weight of water absorbed by a material to weight of dry material.

Water jet High-pressure water stream used for cutting polymer composite parts.

Wet-out The action of saturating a fabric with resin. Also a measure of the speed with which a fabric soaks up resin

Woven roving Heavy, coarse fabric produced by weaving continuous roving bundles.

Y

Young's modulus See Modulus of Elasticity.