FABRIC STRUCTURES FOR MASS SHELTER IN DISASTER AREAS

Research and Development Proposal by the
Advanced Building Technology Team
Department of Architecture
State University of New York at Buffalo
Buffalo, New York 14214
Telephone: (716) 831-3483

ABSTRACT

Expedient provision of emergency shelter becomes essential when large numbers of people are left homeless due to sudden disasters such as earthquakes, fires, floods, typhoons, forced migration etc. which occur frequently around the globe.

While the human and economic misery within the affected communities can strain their emotional and physical endurance, delays in immediate assistance can spread and deepen the hardship and cause wider social and political unrest or extended economic instability.

There is an appropriate emerging technology, namely modern fabric membrane construction, which seems feasible to use for large scale shelter. Such structures could be deployed immediately and for extended periods to protect life and property and to house essential individual, social, industrial and commercial activities. While the use of fabric membrane structure is as ancient as civilization, its most effective modern application has been relatively limited.

The objective of the proposed work is to advance the state of the art of providing shelter for large populations struck by disasters in any part of the world. The shelter will be safe, stable, light weight, easily packaged, stored, transported, erected and re-used. It will be readily available and affordable to large communities, relief agencies and usable within 48 hours in the affected areas. To achieve the stated objectives the R & D team will mobilize the best available expertise in planning, manufacturing, design, organization and management. The development, design, testing and full documentation is expected to require 2 to 3 years of interdisciplinary team effort and costing 1.5 million U.S. Dollars.

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OBJECTIVE

The purpose of the proposed R & D work is to advance the state of the art of providing shelter for large populations struck by disasters. The shelter will be safe (from health hazards), stable (resist external forces), self-contained (does not require additional support), light weight and easily packaged, stored, transported, erected and relocated. To be effective it should be readily available (within 48 hours), affordable to large communities and relief agencies, and usable on a self help basis for extended periods.

The shelter will house individual and social activities and provide protection from the elements, facilitate some continuity of economic/productive/administrative and educational enterprises, and protect equipment and material from deterioration. The shelter also will facilitate essential life support and security for its inhabitants.

SIGNIFICANCE

Observation and analysis of events following major disasters show three successive stages of response:
Stage One: Psychological shock followed by apathy and confusion.
Stage Two: Recovery, feeling of abandonment.
Stage Three: Complaints, accusations, demands.

The needs of the effected population follow this sequence:
1) First aid. 2) Personal safety. 3) Food. 4) Shelter.
5) Personal property (security). 6) Burial. 7) Consolation.
8) Resumption of essential daily activities.

Organizations ministering to the immediate needs typically are military and police organizations providing security and order; the Red Cross providing first aid, health care, food and temporary shelter; local governments coordinating the various public activities; private voluntary organizations performing selected services.

The timely and orderly provision of shelter has the following benefical immediate effects: Relieves the feeling of abandonment, speeds individual recovery, reduces the necessity for undesired migration, minimizes complaints and accusations.

Appropriate shelter, which can be promptly provided, would simultaneously serve the following essential functions: house food storage, preparation and distribution; facilitate urgent and extended medical care; protect from environmental hazards (including after- effects like tremors); provide habitable spaces, essential privacy, sanitation; permit protection of personal property; facilitates essential social functions such as public assemblies, as well as necessary administrative, educational, commercial and industrial activities.

The proposed development will result in an innovative, appropriate construction system. The system will be comprised of sets of coordinated components, materials and hardware which can be transported to any geographic location and erected in time to house large populations struck by disaster.

The proposed research and development project will provide first hand information and experience together with appropriate and feasible design and process solutions for a specific range of application.

RATIONALE

The traditional tent serves as the most common form of emergency shelter today. Tents, however, typically constituting individual structures/enclosures accomodating specific activities in defined interior areas, have limitations. The fabric membrane serves as an exterior enclosure, and posts, cables and other components provide structural support. Integration, combination separation and modification of spaces are not normally facilitated by the traditionally used tents. Controlled transmission of daylight, control of solar heat, fire safety and superior resistance against wind effects are not integrated in the traditional tent fabric. Requirements of privacy, hygiene and isolation are hard to accomodate within one structure. Large tents usually require special skills and tools to erect and maintain which are not easily available in disaster-stricken areas. There are by now, however, alternative approaches and technologies for the provision of emergency shelter which require and deserve full investigation (research, design development and testing) and full scale construction to serve as a prototype for a more appropriate solution.

There is an appropriate emerging technology of fabric membrane construction, the intricacies of which are largely unknown to the building community and its potentials are largely untapped, except for its more traditional versions of strictly limited use. Many of the well known applications of the new longer term fabric construction technology have been large span sport and entertainment facilities and in isolated cases air terminals. Besides the architecturally imposing monumental fabric structures, which are often part of a traditionally constructed building, there are more utilitarian uses for government and industrial storage/warehousing usually of temporary nature. Expertise and experience in advanced fabric construction technology is accumulating, but very few people and groups have direct involvement with ongoing production and projects. As a result of unfamiliarity, there exist misconceptions and misinformation about the design and production potentials, appropriateness, costs, quality, durability and safety regarding the new technology.

TASK

Research, design, develop products/process/system which, if prepared in advance, can begin to satisfy the prevailing variety of essential requirements (see above: "objective" and "significance" fifth paragraph) within 48 hours at the location of a major disaster. Offer the solution in the form of a full technical design and documentation to the disaster relief agency/sponsor for use as a part of the production/contract document for the procurement of the mass shelter products/system. Investigation will extend to the use of the components and materials of the system after it has outlived its primary application and becomes unfeasible to relocate or reuse it as a mass shelter system.

The task will be accomplished in three phases as follows:

FEASIBILITY RESEARCH (PHASE ONE)

Survey priority requirements for shelter in disaster areas.

Assess available technologies and organizational arrangements for the provision of mass shelter in disaster areas.

Survey and assess fabric structure technologies/materials.

Explore fabric structure design and construction options.

Execute cost/benefit analysis of selected options.

Determine criteria for evaluating/testing the proposed system.

Select the most feasible alternative (or options with the best potentials).

Test and evaluate the products/systems.

Reduce options to one.

Complete feasibility report. (Phase One Final Report.)

PRODUCTS/SYSTEMS DEVELOPMENT (PHASE TWO)

Design and select materials, technical solutions, and processes for production, transportation, storage, handling, assembly/erection and relocation.

Develop the proposed solution (including design, process, methods and controls).

Test the proposed solution against given criteria and available options.

Prepare cost/benefit analysis.

Perform value engineering.

Complete product/systems development report (Phase Two Final Report).

FINAL DESIGN (PHASE THREE)

Build prototype structure of approved solution (followed by review of sponsors/experts committee.
Test prototype, evaluate processes used (using simulated conditions).
Refine mass shelter product/systems design/process (based on outcome of test/evaluation).
Prepare technical drawings/documentation.
Complete final design report.
Complete summary report.

TIME SCHEDULE

A detailed schedule will be prepared in advance of the execution of the research contract. The three phases of work could be scheduled for three subsequent years, but if activities were allowed to overlap or be pursued simultaneously, the R & D time could be compressed into two years. (see schedule on page 7)

QUALIFICATION OF THE PARTICIPANTS

The R & D project participation is planned on three levels to ensure in-depth exploration as well as a broad overview of the state of the art and its application.

Level One: The research team comprised of members of the Advanced Building Technology faculty, are all recognized pioneers in their field of research and technology (see included resumes). These members will participate in the day-to-day work supported by the two co-principal investigators, respective research assistants and by specialist consultants as appropriate. The research team will be led by Professor Gunter Schmitz, Director, and and Professor Atilla Bilgutay, Assistant Director, of the Advanced Building Technology Program.

The research team has long standing interest, exposure and experience with fabric structures, products and systems development, shelter technology and design. The proposed project team leaders have personally field-inspected literally hundreds of a large variety of modern architectural fabric structures in North America and overseas. Many of these observations have been documented in form of photographic slides (comprising a vast collection) which are used in academic instruction and research.

Professor Walter Bird, senior researcher, is internationally regarded as the Number One expert in fabric structures in the USA. Both he and Professor Gunter Schmitz, co-principal investigator, recently served on a committee of the National Academy of Sciences on the Use of Stressed Fabric Structures by Federal Agencies, and both have taught the subject for many years. Professor Bilgutay is a specialist in building and structural engineering focussing on tensile structures in the experimental structures laboratory. Professor Csizmadia, senior researcher is an architect with special interest and expertise in systems development and innovative building technology. The Advanced Building Technology team is currently planning the use of modular fabric structures for urban open space and the publication of a fabric structures design manual for use by practitioners and students in the building community.

Level Two: A group of consultants, comprised of selected experts in manufacturing, laboratory testing, design, construction, logistics, etc., will be consulted as required throughout the work.

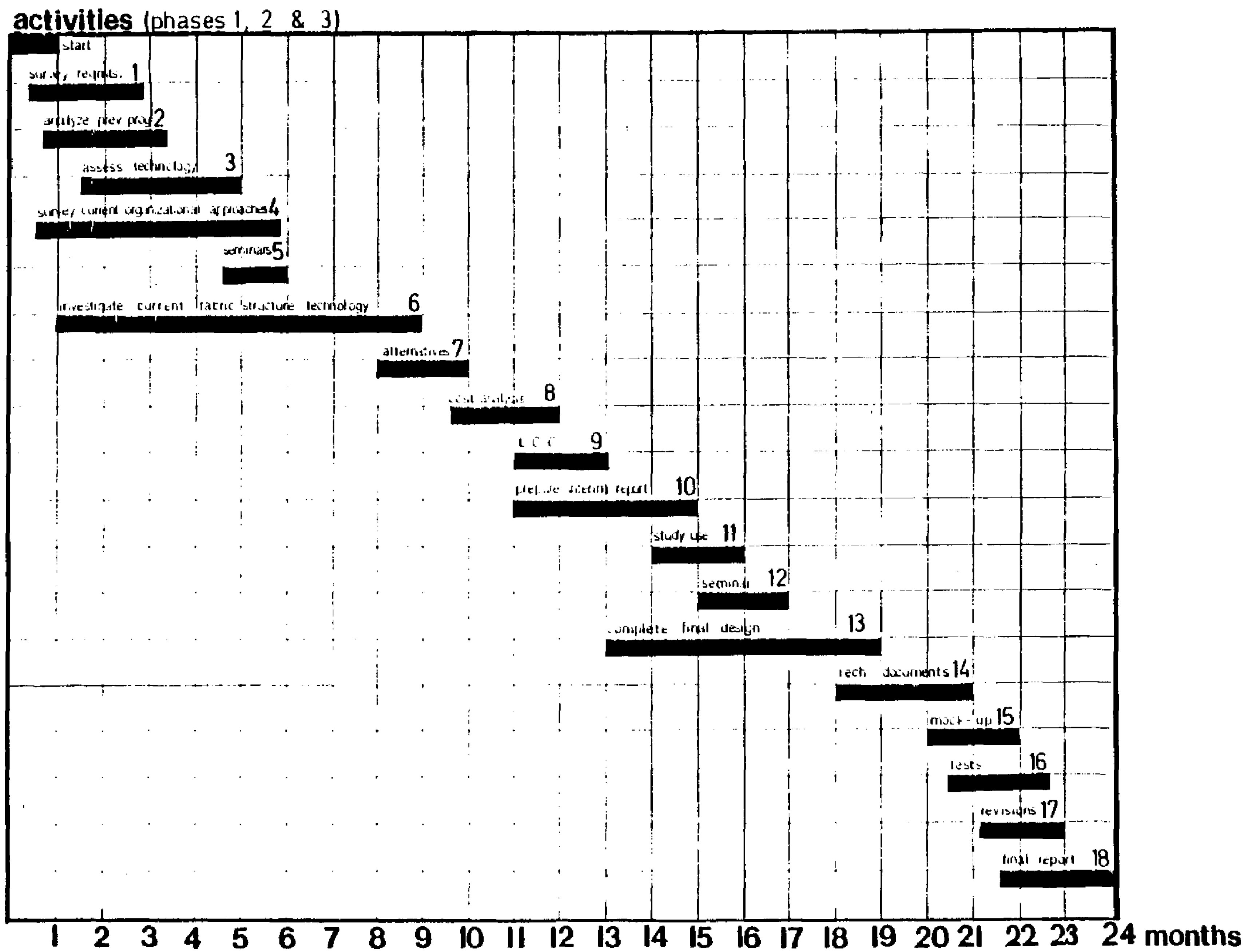
Level Three: A group of expert advisors with broad understanding of the objectives and issues of the work and able to provide insights and advice, not otherwise available to the research team, will be nominated by the sponsors as an Advisory Board. The researchers may assist in providing a list of candidate members for selection by the sponsors. Two workshop/seminars have been scheduled to enable all project participants, consultants, advisors and the interested experts to review the work and exchange ideas.

BUDGET

A budget of $ 1.5 million is required to complete the above proposed work in two years. Money unspent will be carried over into the third year until the project is completed. If preferred, the project work can be scheduled (at the outset) for three years.

CURRENT STATE OF KNOWLEDGE IN FABRIC STRUCTURES.

While pioneering and current experience of fabric structures and related technologies extend to several countries, some of the most signifcant new developments have been taking place in the United States. Some of the most effective design, manufacturing, packaging and construction methods as well as the most durable materials for fabric membrane structures were developed with the help of Professor Walter Bird, Senior Researcher of this project. Much of the design, development and production of the significant large scale permanent fabric structures today takes place in Buffalo, New York, therefore, the writers of this proposal have excellent opportunities to keep pace with the state of the art. A comprehensive bibliography on the subject was recently assembled and made available to the public by the proposers who are continually involved in related research and development. The co-principal investigators of this project have been teaching and researching the subject as part of their normal activities in advanced building technology and now are offering a specialized semester course on fabric structures. Design, and research projects and proposals executed under supervision of project team members include a large variety of approaches and solutions. The inventory of such projects and associated experiences are constantly growing. See attached list: "Student Work on Fabric Structure."



activities (phases 1, 2 & 3)
start
1
analyze prev proj 2
assess technology 3
survey current organizational approaches 4
seminars 5
investigate current fabric structure technology 6
alternatives 7
8
9
10
study use 11
seminar 12
complete final design 13
tech documents 14
mock-up 15
tests 16
revisions 17
final report 18
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 months

ACTIVITIES (see schedule on page 7)

Phases 1 & 2

0. Start up organization (Assemble research team, assign tasks).

1. Survey requirements of disaster relief and shelter.

2. Analyze shortcomings and failures of previous relief programs.

3. Assess contemporary technology of disaster shelter, new alternatives.

4. Survey current organization of disaster relief activities, decision channels. (Methods and approaches of major relief agencies).

5. Conduct seminar/workshop of experts on fabric structures and their potential disaster relief application.

6. Investigate current technology of fabrics, fabric structures, applicable assembly and construction technology.

7. Explore and design alternative solutions.

8. Execute cost-benefit analysis.

9. Conduct life-cycle costing.

10. Prepare interim report.

11. Explore extended use, secondary or tertiary life of fabric structure products/materials.

12. Conduct seminar/workshop of experts on fabric structures and disaster relief application.

13. Complete final design (preliminary, design development and final designs)

14. Prepare technical documentation.

15. Fabricate and construct prototype/mockup structure.

16. Test/evaluate prototype structure.

17. Revise design as necessary.

18. Prepare final documentation and summary report.

METHODS & PROCEDURES

1. Document search & interview experts, prepare/update worldwide data base on disaster relief and related technologies.

2. Develop data base on organizational structures and decision channels and procedures of disaster relief.

3. Assemble products, organize and analyze data on manufacturing techniques, performance of products, tests, manufacture, packaging, handling transportation, erection, disassembly, reuse and maintenance.

4. Develop/assemble data on architectural & engineering form finding methods.

5. Conduct value engineering and life cycle cost analysis.

6. Plan, execute prototype production and testing.

7. Use workshops seminars & consultations with experts and institutional program opportunities to develop, refine, and test information and the potential solution.

SYSTEM DEVELOPMENT PROCESS/PRODUCTS

-Following the specification of functional, technical and technological requirements, survey available materials, components, parts, systems and associated processes and methods.

-Select candidate materials, techniques, etc. for technical testing/evaluation.

-Execute test of candidate materials, components, parts and accessories.

-Select set (of components, techniques, etc.) for use in the system.

-Develop alternative systems solutions.

-Test/evaluate alternatives.

-Select/design system for final development.

-Design/develop/obtain/fabricate all parts of the system.

-Construct prototype assembly.

-Evaluate/test prototype construction.

-Refine/finalize design.

-Prepare full documentation of system
- o drawings
- o production documents
- o construction documents/assembly manuals
- o maintenance instructions
- o disassembly, packaging, reuse manual
- o secondary and tertiary use of materials/components

SOME POSSIBLE COMPONENTS OF THE SYSTEM TO BE CONSIDERED

1. Rolls or modular panels ready for construction
2. Spools of cable or pre-cut finished cables
3. Telescoping light weight columns and foundation posts
4. Standardized connectors, joint components
5. Anchorage components.
6. Procedure manuals
7. Audiovisual packages to explain methods of self-help assemblies/construction and operation.

STATE OF THE ART OF FABRIC STRUCTURES: AN OVERVIEW

While the use of fabrics for shelter is ancient and has been widespread in some cultures, it has been only recently that the technique has achieved respectability in modern construction. Today prestigious and monumental buildings are constructed with durable, permanent, attractive and safe fabrics. This has been made possible by recent material development, structural systems analysis and computer aided design. Development of specific fiber production, spinning technology and coating processes resulted in noncombustible, radiation resistant, lightweight membranes with structural properties enabling them to cover large spaces economically. Combined with cables, anchors and other components, building systems can be produced to house practically any activity and to protect people, material and livestock in any part of the globe.

The design, production, packaging, handling and construction of high performance modern fabric structure systems require considerable expertise, skill and effort. Only a small number of organizations today are technically equipped to handle them competently. Expertise in large scale permanent fabric construction is even further limited.

A recent international architectural fabric structures conference (held in Orlando, Florida, 28, 29, 30 November 1984) provided the most recent opportunity to formulate an overview of the state of the art as it is seen by the most prominent experts (designers, producers, researchers, inventors) internationally. Information presented during this conference and associated field visits confirmed the view of the investigators that much wider use of the innovative technology is possible, feasible, beneficial and overdue. The era of exclusive use of monumental structures of high performance fabric membrane materials is coming to an end. Understanding, use and acceptance of the new techniques and forms are on the increase constantly in different parts of the world.

Further increase and diversification of modern fabric structures will largely depend on specific systems development efforts and sponsorship of same. Whether or not the availability of the innovative materials will result in a quantum jump of building technology and in the provision of shelter, especially for those in urgent need, will depend largely on the sponsorship of appropriate systems development. Design and construction of unique monumental projects, no matter how advanced they may be, will not accomplish these objectives. Nevertheless the expertise and experience thus gained are essential to achieve appropriate and wider use of the technique.

In industrial systems development typically the sponsor determines the objectives and the nature of the product and also becomes the major beneficiary of the outcome. Systems development of the last decades in the building industry has taught a hard lesson in the relationship of sponsorship and product, for example when well meaning programs have resulted in inflexible mass housing of inappropriate plans and designs.

The success stories of systems development on the other hand, invariably are tied to organizations existing to promote and protect a balance of human and societal interests and objectives catering to a wide market of consumers. The sponsoring agency of fabric structure systems development for emergency shelter will naturally determine who will be the final beneficiary of the proposed effort.

Student Work on FABRIC STRUCTURES

Fall 1978	ARC 544	Gordon, "Technology of Pneumatic Structures", term paper, supervising faculty: Gunter Schmitz.
Spring 1982	ARC 545	B. Cahill, S. Schaffer, N. Sgro, "Dual Wall Inflated Membrane Structures", summary, supervising faculty: Gunter Schmitz.
	ARC 545	D. Conroy, C. Marcella, R. Odorico, and M. Borges, D. Mailing, H. Matern, and J. Ferentinos, F. Genese, "Three summaries of lectures by Walter Bird - US Pioneer in Architectural Fabric Structures".
	ARC 545	J. Delaney L. Ekram, C. Saunders, "Grid Shells and Cable Nest as Supports for Fabric Enclosures", supervising faculty: Gunter Schmitz.
	ARC 545	T. Eckmair, L. Roberts, C. Chang, "Building with Fabrics", summary, supervising faculty: Gunter Schmitz.
Fall 1982	ARC 544	K. Burzynski, D. Paschkai, E. Tamburri, "Teflon Coated Glassfiber Fabric: Plant Visit Report - Chemical Fabrics Corp., N. Bennington, VT", supervising faculty: Gunter Schmitz.
	ARC 544	J. Fung and S. Khan, "Case Study: Chemfab's Weaving Facility, Manchester, NH (Speciality Weavers for Industry)", field visit report, supervising faculty: Gunter Schmitz.
	ARC 544	M. Nelson, R. Odorico, N. Sgro, J. Tucker, "Teflon Coated Glassfiber Fabric: Membrane Fabrication Facility, Birdair/Chemfab, Buffalo, N.Y.", plant visit report, supervising faculty: Gunter Schmitz.
	ARC 544	W. Park and H. Han, "Case Study of an Air Supported Fabric Stadium: Carrier Dome, Syracuse University, NY", supervising faculty: Gunter Schmitz.
	ARC 499	J. Park, "Fabric Structures: Types, Material Properties, Design, Structure Systems, Construction, Roof Safety, Case Studies", supervising faculty: Walter Bird.

Fall 1983	ARC 599	W. Park, "Small-Span Modular Framed Tension Fabric Structure for Pedestrian Circulation", supervising faculty: Walter Bird/Gunter Schmitz.
	ARC 499	S. Holland, "Small-Span Tension Fabric Structure for 'Permanent' Application", supervising faculty: Walter Bird.
Fall 1984	ARC 599	B. Chibber, "Shade Structures in Fabric Membrane Material for Hot/Dry Climates", supervising faculty: Walter Bird.
	ARC 599	R. Saxena, "Transportable Multipurpose Tension Fabric Structures for Conditions Prevailing in Developing Countries: Their materials, fabrication, erection, and functional application" supervising faculty: Walter Bird.
Fall 1983	ARC 455/555	"Development of Prototypes: "Tension Fabric Structures for Vehicle Enclosure", Student projects, supervising faculty: Atila Bilgutay.
	ARC 455/555	"Cable Structures for Stadiums", Student projects, supervising faculty: Atilla Bilgutay.
	ARC 455/555	"Single-mast, fabric membrane cone with radial reinforcement cables", scale models of experimental student projects, supervising faculty: Atilla Bilgutay.

Faculty Work on FABRIC STRUCTURES

Atilla Bilgutay (Consultant),
Light scale temporary Fabric Structures for Ankara Food Fair, Ankara, 1972

Gunter Schmitz
"Bauen mit Membranen: Flaechentragwerke" (Building with Membranes: Surfact Structures)", (in German), Form + Zweck, Berlin, Vol. 14 (1982), No. 3, pp. 16-29.

Gunter Schmitz, Atilla Bilgutay, Tibor Csizmadia, Building with Fabrics and Cables: A Bibliography, Documental as IBTI-6 in the series Innovative Building Technology Information, Department of Architecture, SUNY at Buffalo, April 1984, 38 pp.

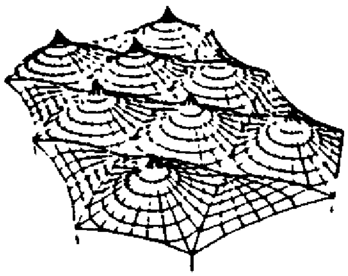
Spring '83
Prof.
Walter Bird

ARC 499/599 Independent Study Fabric Structures [Elective]

For prerequsites and details
Contact:
Prof. Gunter Schmitz
308.C Hayes

Lightweight Roof Systems: lecture on Building Systems Development

by Prof. Attila Bilgutay
SUNYAB
324 Hayes
Wed, 22 Sept 82
01:30-04:00 pm

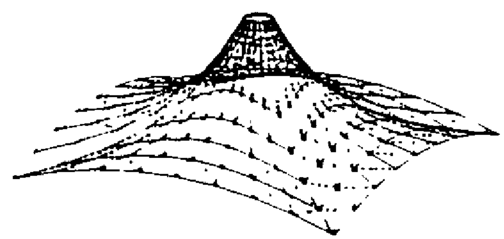


Simple Design Methods for Tensile Fabric Structures

Prof. Walter Bird
Open lecture for
ARC 352/552 Structures 1, et alies

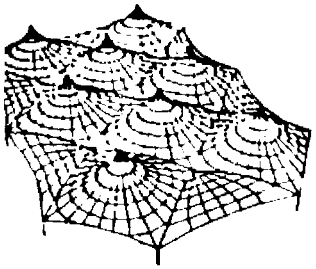
301 Crosby SUNYAB
Wed, 27 Apr 83
11:00-12:00

Tensile Fabric Structures



Prof. Walter Bird
Open lecture for
ARC 352/552 Structures 1, et alies
SUNYAB

301 Crosby
Wed, 16 Feb 83
11:00-12:00



Walter Bird lectures on Building with Fabrics

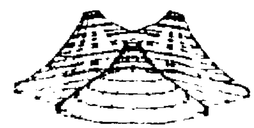
Suspension and Inflatable Structures

SUNYAB
Main Street Campus
Cary Hall 246
We 15 Sept 82 09:00 - 11:00 am

Mandatory for students in
ARC 455/555 Structures 3
ARC 453/553 Structures 2
ARC 544 Building Systems Technology 2

Recommended highly for everybody!

Fall '83
Prof. Walter Bird



ARC 499/599 Independent Study: Fabric Structures (Elective)

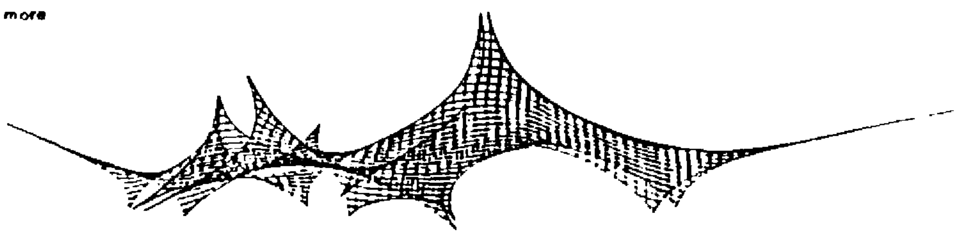
Prerequisites:
ARC 545 or 544 or 554 or 555
For details see
Prof. Bird, Schmitz or Bilgutay (Hayes)

Prof. Ewald Bubner
University of Essen, Germany

Wide Span Designs

light weight envelope structures:
appropriate use
form finding methods
modelling

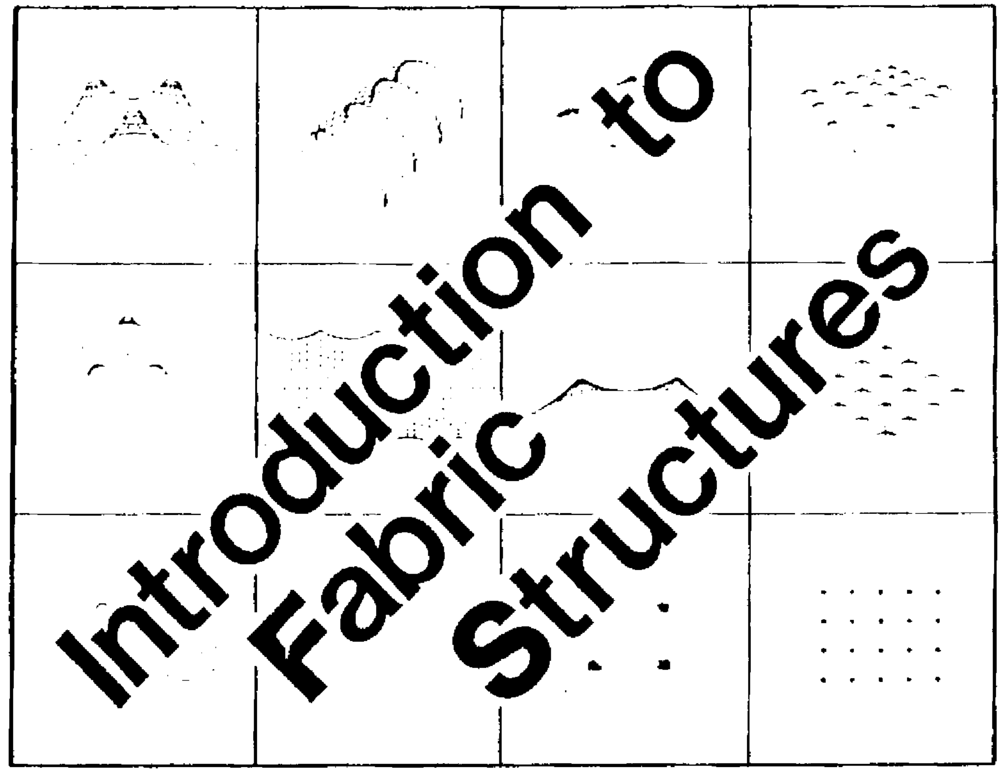
International projects:
membrane roofs
retractable covers
large-scale greenhouses
lattice shells
more



Thu 20 Sept 84
03:00 - 04:30pm
Rm 5 Acheson [Chemistry Bldg.]

Prof. Walter Bird

Introduction to Fabric Structures



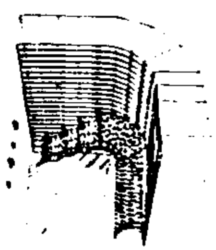
Lecture for
ARC 453/553 Structures 2
SUNYAB
147 Diefendorf
Wed 19 Sept 84 12:00 - 13:00

All Others are Welcome

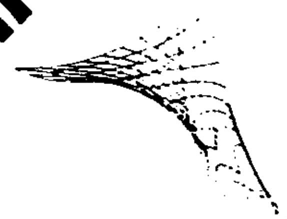
Prof. Vinzenz Sedlak

Director - Lightweight Structures Research Unit
University of New South Wales, Sydney

Open Seminar



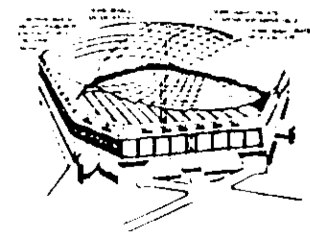
Innovative Architectural Technology



Membrane Structures in Australia

Thu 15 Nov 84
02:00 pm (followed by informal discussion)
Rm 239 Hayes

Prof. Walter Bird



Non-Traditional Structures in Fabric

"Air Supported and Tensioned"

Lecture for
ARC 455/555 Structures 3
ARC 344/544 BST 2
SUNYAB
201a Hayes MSC
Wed 19 Sept 84 9:00 - 10:20am

Department of Architecture
School of Architecture and Environmental Design
State University of New York at Buffalo

(Spring 1985)

ARC 357/557 Fabric Structures
Seminar (elective course)
3 credit hours

Catalog Description

Theory and practice of building with stressed fabric membranes. Principles of cable structures, nets, tension membranes, air supported and inflated membranes. Minimal surfaces, curved surfaces, materials, joints, technical details. Design development, production, erection, performance in use. Building typology and case studies. Small design exercise with scale model studies. Field trips.

Conceptual Goals

Provide the theoretical background for understanding major scientific/technological principles governing the emerging field of architectural fabric structures. Bring architectural students to a basic level of competence from which they can enter a design studio focusing specifically on the design development of modern fabric membrane structures for identified applications. The course is an essential element in the M.Arch. program in Advanced Building Technology, but provides a supplement to all architecture programs on all levels.

Subject Matter

Geometrical, mathematical and technological aspects of fabric structures, principles for design development, patterning and detailing, architectural interface, user aspects, environmental controls, life safety, manufacturing, erection and a state-of-the-art review of relevant building types realized as fabric structures.

Methodology

The class meets for a total of three hours a week, starting with an introduction to the technical/theoretical principles of stressed fabric structures. Soap film experiments regarding minimal surfaces and an overview on modern fabric membrane materials and their characteristics follow. Air supported fabric structures are covered as well as dual wall inflated membrane structures, mechanically tensioned fabric structures and grid shells. Classes on production, quality control, construction, energy performance and maintenance of fabric structures round off the sequence of topics. Up to three field trips permit direct field observation of various aspects of fabric structures technology. Some scale model studies are required.

Instructors

Gunter Schmitz, Prof. with
Atilla Bilgutay, Prof.,
Walter Bird, Adjunct Prof.,
Mark Ernst, Asst. Prof.