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Prof. Land's professional experience includes major offices in London and New York and projects in Africa and the Middle East. He has initiated and directed major programs and projects for the United Nations in South America for social housing, developing, and building innovative earthquake-resisting construction technologies. In collaboration with NASA, Prof. Land prepared research proposals and shelter systems designs for the U.S. First-Lunar-Base Project. He has also designed and fabricated large-scale apparatus for accurate and interactive reproduction of solar geometries and trajectories (heliodon) for light examination of single structures and urban complexes, used extensively in assessing environmental densities in Chicago.

Prof. Land leads with advanced students a long-range, research-based design development program at IIT consisting of two studio teams for tall and wide-span projects with innovative structures and natural energy systems. As part of this, he maintains an extensive database of international pioneering and contemporary projects, including developments in advanced technologies and materials and products in related fields such as automobile, aviation, marine, space, sports, etc.

He carries out professional practice and consulting in architecture, technology, and planning, and is a visiting lecturer and speaker at universities and conferences in the United States and overseas.

Experimental Tall Structures and Natural Energy Systems

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This presentation will show a number of tall building projects with innovative structures and energy systems selected from a range of proposals developed at the Illinois Institute of Technology by the author with advanced students over several years. They include concepts such as multiple co-supportive tubes, geometries informed by nano-tube lattices, exo-skeleton and global tensegrity, shell-action diagrids, light-pipe penetration, etc.

The rising costs of fossil fuels and depletion of non-renewable resources signal the end of cheap energy and the beginning of the end of the petroleum age. It is desirable that architects and engineers focus on this alarming and approaching reality by developing experimental proposals for structures and envelopes designed to both produce and conserve energy. A changing energy reality could eventually impact the future form of tall buildings, as well as urban and regional settlement patterns.

EXPERIMENTAL TALL STRUCTURES AND NATURAL ENERGY SYSTEMS

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Abstract

New challenges in energy require unique solutions in structures, and fresh ideas in structures and materials generate new concepts and solutions. Consequently, the areas of structure, energy and materials are becoming closely intertwined and advances in these areas influence progress in tall building design and technology. This presentation will show a number of tall building projects with innovative structures and energy systems selected from a range of proposals developed at IIT by the author with advanced students over several years. They include concepts such as multiple co-supportive tubes, geometries informed by nano-tube lattices, exo-skeleton and global tensegrity, shell-action diagrids, light-pipe penetration, etc. The rising costs of fossil fuels and depletion of non-renewable resources signal the end of cheap energy and the beginning of the end of the petroleum age. It is desirable that architects and engineers focus on this alarming and approaching reality by developing experimental proposals for structures and envelopes designed to both produce and conserve energy. A changing energy reality could eventually impact the future form of tall buildings, as well as urban and regional settlement patterns.

EXPERIMENTAL TALL STRUCTURES AND NATURAL ENERGY SYSTEMS

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This paper summarizes the characteristics of a range of experimental projects, which will be shown and described in detail with illustrations at the CTBUH 2005 Congress, N.Y. The overall emphasis is on innovative structures and natural energy systems. Some projects focus on structural innovation, some on energy systems and others integrate both in various ways.

The idea of living in harmony with nature is beginning to take on a new meaning. In the past, different cultures and economies have devised ways to live comfortably in hostile climates, which are excessively hot, cold, arid or humid. Vernacular built-form solutions to these challenges often are very interesting; exhibit considerable inventiveness in materials and structures with a sophisticated understanding of the laws of physics. A great deal of this work is often achieved with simple and readily available materials. These traditions extend form early history to the beginning of the petroleum age and cheap energy in the major climatic regions of the world.

With the beginning of the end of the petroleum age in sight the concept of living in harmony with nature begins to take on a contemporary and urgent meaning, if we are to anticipate the future and a decline in non-renewable resources in particular fossil fuels. The future will require a built environment, which conserves the use of energy efficiently, and buildings that generate, as far as possible their own energy needs with appropriate technologies such as wind turbines, photo voltaics, solar thermal collection, geo-thermal resources, etc. Achieving some of the objectives can require building envelopes of unusual arrangement or configuration, which are difficult to achieve with conventional approaches. This requires innovative structures using new materials or existing ones in new ways.

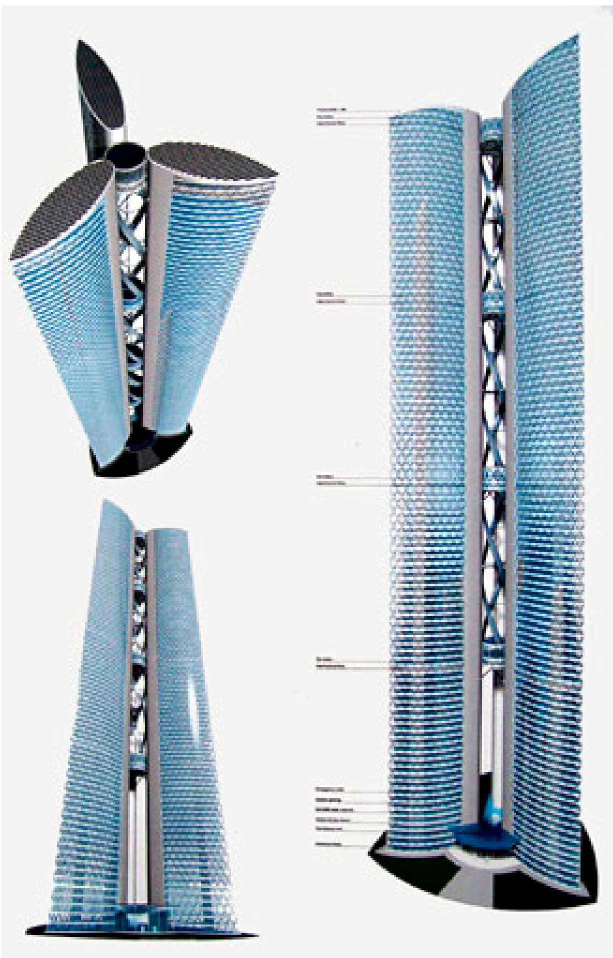
New challenges in energy are generating unusual solutions in structures, and new ideas in structures and materials are promoting fresh concepts and solutions. Consequently, the areas of structure, energy and materials are becoming closely intertwined and advances in these areas will influence progress in tall building design and technology. Inventing appropriate new structures and configurations requires lengthily experimentation, hypothesizing and evaluation to arrive at solutions with potential. Experimentation based upon ideas from other advanced technology fields are also opening up important new ideas and technologies for both tall and wide span structures.

Though this conference is about tall structures, the wide span structure relates to it in two ways. In experimental development work ideas emerging from wide span investigations may stimulate tall structure ideas. And, with increasing frequency, wide span structures surround the base of tall buildings and some visionary proposals integrate the energy concept or systems of the two parts. With this interaction in mind reference is made to some wide span projects in this presentation, which are particularly relevant.

This author leads two design-development, research based studio teams with advanced students in the College of Architecture at the Illinois Institute of Technology. One deals with tall building types and structures and the other with wide span types and structures. The thrust of the work in both areas in on innovative, experimental structures with naturally powered energy systems. Students and collaborators in both groups begin projects with an extensive research phase, which investigates and documents latest projects and ideas in the two areas. In this way, new projects undertaken by the groups can incorporate cutting-edge developments in technology and design where appropriate. Following the research phase members of the team assume a diagrammatic concept to be intensively developed parallel with continuing research. Concepts developed for structures and energy systems for tall buildings (in steel and concrete) include trussed tubes, hypar surface tubes, clustered co-supportive tubes, shell-form diagrids, tensegrity and geodesic geometries, etc. They also include double skin facades, and interior ecological landscaping for environmental enhancement.

In anticipation of future energy demands, a new area of concept development is tall structures with integrated wind turbines and photovoltaic energy systems. Our research is examining available and new turbines; new building forms are being developed to accelerate wind flow velocity for mono and omni directional wind flow concepts with both stationary and yaw-able turbine installations. The ultimate objective in energy efficiency is for a tall building to be fully equipped with energy generating installations such as wind turbines, photovoltaic arrays, solar thermal collectors and geo-thermal equipment, and energy conserving features. Photovoltaic and double skin facades are a feature of most of the projects in this presentation. P.V. arrays are both stationary or in track-able installations.

An extensive database and record of new projects and technologies have been built up from our research activity. Also, a unique library and data collection is maintained including early projects by pioneering modern movement architects and engineers. All experimental development work should initially review the work and visions of the pioneering structural engineers and architects such as Fuller, LeRicholais, Nervi, Otto, Suchov, Torroja, Weidlinger, Zetlin and others. Historical reviews should also include the engineering pioneers of the industrial revolution. There are many interesting ideas, which have contemporary meaning in both distant and recent history.



(Fig. 1)
Clustered airfoil towers.
Focused wind-flow on middle turbine. Crossover circulation between towers at double height middle sky gardens.
David Osivnik

Alternative Vertical Circulation and Security (Fig. 1)
Linked towers, decentralized or alternative vertical circulation concepts are new and important considerations with the growing concerns for security. However, in addition to security, several other advantages may be offered by these concepts. Some of them are: linked towers give quick, alternative exit at rush hours as well as in emergencies; co-supportive structural interaction at contact edges;

concentration and acceleration of wind-flow onto rotors in centrally located wind turbines; linkage and cross over points can be suitable locations for sky gardens; and at contact edges between semi independent towers vertical circulation can be located which can be conveniently and effectively fire protected. Decentralized vertical circulation in single tall structures can offer several exit points at minimum access distances. Each may be part of a cluster, which also contains other services, can be conveniently fire proofed and can be designed as mega columns. Large structural columns placed at the corners of a floor plate, can offer large column free floors. Three, four or five sided floor plates also offer wind power potential. Wind naturally accelerates at the corners of polygonal towers at which points can be attached vertical axis turbines possibly with variable pitch wind deflectors. Several projects incorporating the above feature have been developed two or three of which will be presented at the conference.

Light Pipe Transmission.
In this project the entire building and its structure is shaped around the light-pipe or light- flow concept. Light is captured externally at the perimeter of the building every eight double floors, and channeled into and downward through the center of the building using high performance reflectors. A proportion of the center light flow is intercepted and reflected horizontally into each office floor. In this way the working floors are naturally lit from both sides: from the exterior windows and from the middle ‘light pipe’ source. The exterior surface of the tower inclines outward in eight double floor stages, from each light intake floor. The maximum inclination is on the south side of the tower gradually reducing on the east and west sides to vertical on the north, elevator side. This refinement in the building form reduces solar gain on the façade and permits light entry at the bottom setbacks where landscaped gardens are located.

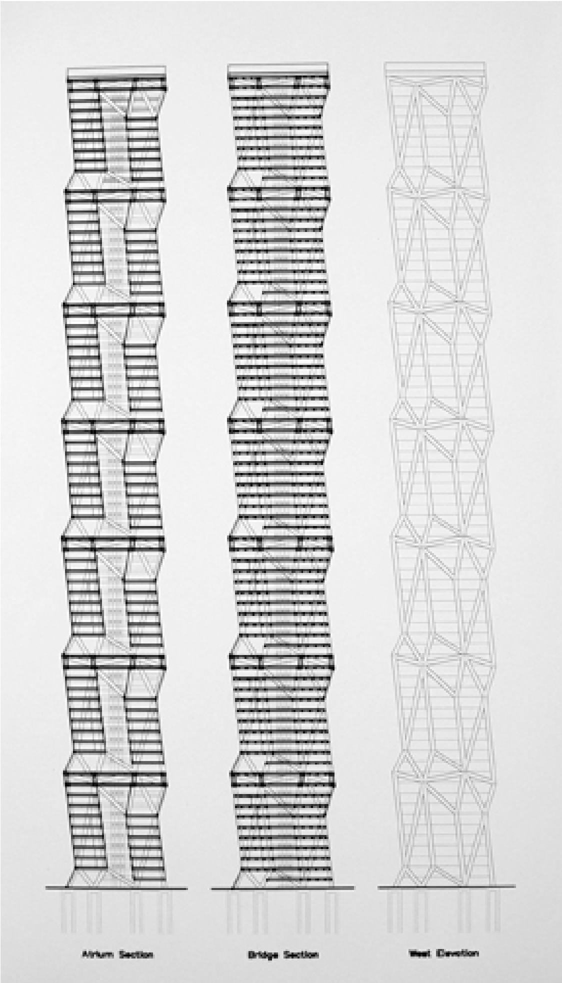


Fig. 2
South-north, continuous through atria.
Pressure differential induced cross ventilation.
Through light flow to middle atria, continuous landscaping.
John Kelley

Cross Atria (Fig. 2)
This project has wide atria, which penetrates through a slab-like building orientated east west. An atrium opens on the south side penetrating horizontally, then drops vertically through eight floors, exiting horizontally on the north side. The glazing at this atrium opening on the south side is angled to reduce solar gain in summer but permit solar gain in winter. The profile of an atrium is dimensioned to allow light and sun in winter and summer to penetrate into the center of the building. The profile brings natural light to the interior atria side of each office level. The outside air pressure differential between each side of the building naturally ventilates the building through the atria, regulated by adjustable intakes and exits.

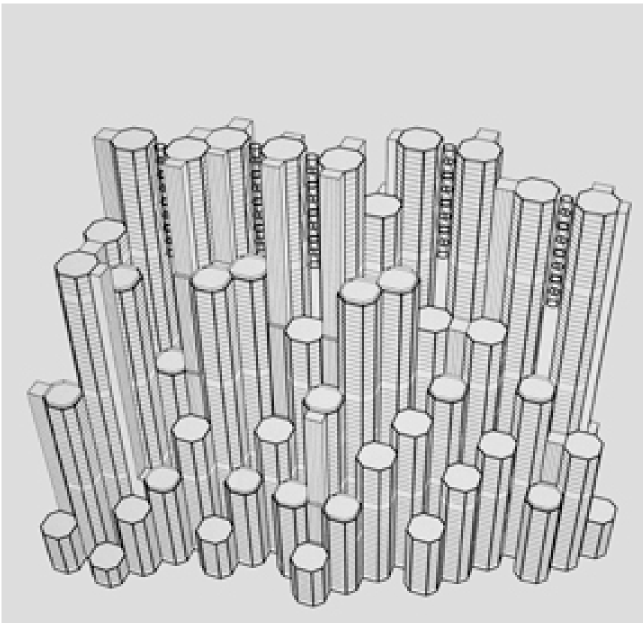


Fig. 3
Clustered, co-supporting trussed tubes.
Separate modules for vertical circulation and services.
High-level turbines between tube clusters.
Connected roof gardens.

Clustered Tubes (Fig. 3)
The concept of tall structures with co-supportive, clustered, adjacent structural tubes is well known. Two projects on this principle have been developed using six and eight sided tubes with isogrid floors. Vertical circulation in the six-sided tube solution is placed within selected tubes. Vertical circulation and services in the eight-sided tube solution are conveniently placed in the free spaces between the tubes, which avoids penetrating the structural isogrid floors within tubes. Vertical circulation and services are conceived as separate prefabricated modules. Isogrid floors comprise 'star' form shop-made units accurately assembled on-site. Extended upper level tubes support vertical or horizontal axis wind turbines.

Nano Tubes
The walls of nano tubes (Fullerenes) indicate stiff lattice geometries, one or two cells thick. These tubes have been carefully replicated and their characteristics studied in relation to a building structure. Proposals for several tall building structures have been developed with repetitive modules. One project will be shown using steel tubes and cast steel nodes to form primary structural 'star' type self-bracing components. These are assembled with bolted connections at the nodes to form three dimensional, double lattices with steel cable cross braces. Folded plate steel floors span from middle core of the cylindrical building form to the exterior double lattice, steel structure. The floor loads are transferred concentrically to the middle of the exterior structure at the node intersections through a load transfer fitting attached to the end of the folded plate floor units. The exterior structure has an outer and interior membrane, forming a double-skin façade. The ventilated cavity is linked to ducts in the folded plate profile of the floors forming a continuous air circulation loop for moving energy around the building.

Lost Formwork
Tall concrete structures suffer the disadvantage of slow erection time because of time consumed by formwork erection, concrete setting and formwork dismantling. A proposal has been developed to greatly reduce overall erection time by using pre-made 'lost' formwork, dimensionally coordinated for all adjacent parts of the structure. The forms are thin, light weight, fiber reinforced cement units accurately factory made to fit together, be self-supporting and leak proof. The first formwork technology is developed in detail for a diagrid cylindrical tower, but can be applied to an orthogonal structure. The main components of the formwork for one floor from the bottom up, following the erection sequence, are: the bottom knuckle at perimeter beam; columns intersection; column tube; top knuckle at perimeter beam; columns intersection; and perimeter beam casing. Pre-cast, floor units are top grouted and post tensioned. Reinforcement is placed inside the diagrid forms in three stages with appropriate splices as erection proceeds per floor. The assembled formwork for one floor of knuckles, columns and perimeter beams are concrete pump-filled in one operation. After the concrete is set on one floor the operation is immediately repeated on the floor above. No dismantling of formwork is involved. As the formwork is strong it can assume some floor loading before the concrete reaches full strength permitting formwork erection and concrete placement for the floor above on an accelerated schedule. As formwork components are factory molded with a high quality exterior finish limited post construction finishing would be required.

Tensegrity Concepts
Several tall buildings proposals with tensegrity ideas have been developed based on two principles. One principle is exterior tensegrity structure and the other considers the entire building form as a three-dimensional tensegrity entity. Projects in both steel and concrete have been developed for the two approaches.

Fig. 4
Lens shape tower, shell-form diagrids.
End mounted turbines with adjustable, focusing wind-flow ailerons. Interior south side landscaping.
Markus Willeke

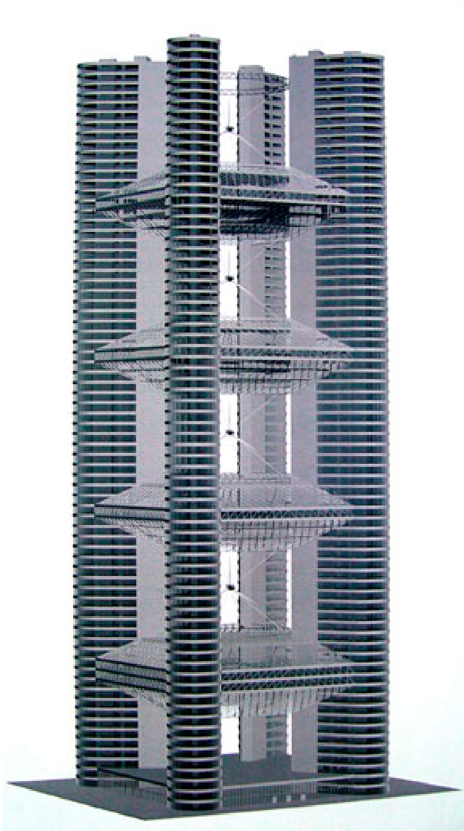


Fig. 5
Corner pylons support middle 'flying' garden atria.
Omni-directional, yaw-able middle turbines.
Motorized side stay end anchors.
Johannes Smith.

Wind Turbines (Figs. 4 and 5)
A tall building can be considered as a mast on which appropriate wind turbines may be mounted for the generation of electrical energy for the building itself or for export. A new (September 2004) and very important comprehensive study "Evaluation of Global Wind Power" done at Stanford University funded by NASA and Stanford demonstrates that a small percentage of available global wind power is sufficient to supply all the world's energy and electricity needs! The report concludes that 'several practical barriers need to be overcome to fully realize the potential!" In a separate development the German Government has recently concluded that wind energy in its present form is too costly. Germany presently has more wind farms than any other EU country though less wind resources. It notes that important reasons for high cost of electricity from wind are that wind farms are too far from where energy is consumed in the industrial and population centers. The findings of the Stanford and German studies are complementary. Energy losses from transmission and transmission infrastructure costs are substantial. Both will be eliminated by tall structures with the features under development. With the gradual introduction of this concept the urban and regional settlement pattern will need to be planned for an optimum tower density and a distribution pattern, which considers wind shadowing.

Tall structures with turbines may be either single structure with exterior, top mounted or inserted turbines, or are several structures clustered and shaped to direct and accelerate wind flow to a middle turbine. Several concepts for tall structures with integrated wind turbines have been developed. A wide range of wind turbines is commercially available and new experimental models are being developed by industry. An international survey of model wind turbines is on going to document the characteristics of the different models and their suitability for tall structures. Building forms have been modeled to intercept, concentrated and accelerate wind flow to drive appropriately designed and located rotors and turbines.

Tall structure concepts of this type are essentially two types. Those, which are designed to operate in locations where wind may be from any direction, and those which operate in winds that are predominantly from one or its opposite direction. Several projects of both types have been developed. The aerodynamic efficiency and energy output of the wind turbine projects, which have been designed, will be assessed later this year (2005) using CFD strategies. The omni directional concept uses both horizontal and vertical axis turbines. To greatly improve the efficiency of horizontal axis propeller type turbines in omni directional wind locations, turbine mounts need to rotate so that the propellers are always perpendicular to the incoming changing wind front. Several proposals for turning or 'yaw-able' turbines have been developed and two will be shown. One employs a new down-wind type of turbine, which reduces the distance between the side stays of the turbine mount to facilitate turning of the turbine mount.