Basic Principles of Building Science

Dear Colleagues: Teaching building science is critically important to all students in architecture and engineering. It is much too risky for the architect to depend solely on the technologist's understanding of the forces which impact the building. Fortunately the basic principles which govern the performance of the building are fairly simple to understand if they are properly presented. The following basic principles are not comprehensive, but will provide guidance to students who one day hope to be involved with the design and construction of buildings.

2.1 Forces exist solely to achieve BALANCE. Water on one side of an enclosure creates hydrostatic pressure. Similarly, air pressure caused by wind or stack effect is another force trying to equalize itself. Heated buildings in the winter will lose heat to the exterior because the higher temperature inside is seeking to equalize itself with the lower temperature outside. Differential levels of humidity, sound, and light also create forces across the building enclosure. If these forces cannot be relieved, the building enclosure must be designed and built to withstand the resulting effects. Natural deterioration of building materials may be nature's way of achieving balance through regeneration.

2.2 Materials will not DETERIORATE if one of the conditions for deterioration is absent. Wood will rot when subjected to all of the following five conditions: presence of water, spores, oxygen, optimum temperature, and a food source. Rot will cease if any one of the five conditions is absent. Similarly, rusting of steel can only occur in the presence of oxygen and moisture. Without moisture or oxygen, the rusting process is retarded.

2.3 Materials change DIMENSION with temperature change and moisture content. All materials increase in dimension when heated. The rate of dimensional increase (thermal coefficient of expansion) varies depending on the properties of the material. Similarly, all materials will contract when cooled. However, when materials change from one state to another such as water freezing, there will be a rapid expansion.

Moisture will cause some materials to increase in volume. Water causes swelling of soils and most organic substances. As the substance absorbs more water the material continues to expand. The expansion of clay masonry products from moisture buildup may result in cracking, lateral movement, and other types of wall failures.

From Kidder-Parker Architects' and Builders' Handbook, 18th edition, 1931, courtesy of James Ambrose

Polarities: Love or Knowledge?

The essence of good teaching is love—love of one's subject matter, love of one's students, love of the process of transmitting knowledge from one generation to the next. From love comes the contagious enthusiasm that lies at the core of effective teaching. In the early years of one's teaching, love and enthusiasm can even outweigh occasional lapses in one's command of the subject matter. Without love, teaching is a hollow exercise that is of little benefit to either student or teacher.

The essence of good teaching is knowledge—a thorough knowledge of one's subject matter, a knowledge of how to organize it so it is easy to understand and to learn, a knowledge of how to read and react to one's students' feelings in the classroom or studio. Teachers who rely on personal rapport with their students to cover for insufficiencies of knowledge don't last long. Teachers who can deliver the goods, year after year, are the ones who are truly effective.

Where do your thoughts lie on the spectrum between these poles? We will print the most interesting responses.
2.4 No material is infinitely strong. All materials will eventually fail under some level of loading or stressing. Strengths of materials are affected by environmental conditions and aging. Cold temperatures may cause brittleness in substances such as wood, plastics, steel, etc. Ultraviolet radiation from the sun will break down some materials at the molecular level.

2.5 Heat travels to the colder side. Cold temperatures do not travel into a house in the winter unless they enter by air infiltration. If part of a wall feels cold, it is due to heat being conducted out at a faster rate than adjacent surfaces. Areas of thermal bridging clearly demonstrate this phenomenon.

2.6 Heat conduction cannot be stopped. Heat transfer through RADIATION can theoretically be stopped by a perfectly reflective barrier and heat transfer by CONVECTION can be stopped by physical barriers. Heat transfer by CONDUCTION, however, cannot be stopped, whatever the substance. Even the best thermal insulation can only slow down the rate of heat flow through conduction.

2.7 The weakest component will fail first. A chain is only as strong as its weakest link. This statement is applicable to many instances of failure in building science. We know that cracks will form along the path of least resistance. A thermal bridge is considered the weakest path of thermal resistance.

2.8 There is always a point of diminishing return. In buildings, very long free spans also have a point of diminishing return. The longer the span, the more structure is needed to carry its own weight. The first inch of insulation is thermally the most effective. Subsequent insulation thickness is less effective. Eventually the additional thickness of insulation will have marginal benefit.

2.9 Materials must have sufficient time to cure under optimal conditions. The durability and strength of concrete depends on adequate curing time and an optimal environment. If the temperature is too hot, a rapid loss of water will dry out the concrete too quickly. If the temperature is too cold, the water in the concrete may freeze. Adhesives must be held in position for a recommended period before they can achieve their full strength. Paints and other coatings must have sufficient time and be in optimal environmental conditions for them to cure properly.

2.10 Water and buildings do not mix. This last principle is perhaps the most important principle of all. Water, in all of its forms such as a liquid, vapour, or solid (ice), can affect the performance and service life of buildings. It is imperative to ensure that the amount of water, vapour, and ice does not exceed the tolerable limits of the building enclosure. In total, the damage caused by water (although a very slow process) may greatly exceed the combined damage of all natural catastrophes in the world.

The above principles may be simplistic, but when explained in relationship to the building industry, they become exceedingly clear and memorable. As teachers, we have as much responsibility to instill the proper attitude in our students as to impart knowledge. Making concepts simple and relevant is one of our primary pedagogical goals. What do you think? I would love to hear some of your basic principles of building science. Tang G. Lee, Faculty of Environmental Design, The University of Calgary, Calgary, Alberta CANADA, T2N 1N4. (403)220-6601.
On Lifting an Egg With a Kite

Dear Colleagues: Too rarely do we gear problems in structures courses to actual hands-on experimentation. When performance criteria for the end product of a design process can be established clearly, students are inevitably led into a process of experimental design, testing, and affirmation. The principles thus learned, once mastered, can easily be put to use in the design of other projects, in a repeating cycle of Designing, Computing, and Producing. The results the students produce will not be uniform, like the answers to a purely mathematical problem. They will not be clearly right or wrong, or even optimal; but most will be acceptable, like real structures in the real world.

It was with these convictions that a final examination project, to design a kite to lift an egg with a limiting line tension of two pounds, was assigned to 49 students in Structures 1 at SUNY Buffalo in the Spring of 1993. This problem tested students' understanding of wind forces (induced drag and lift), dead and live loads, and vectorial equilibrium, including having to design a bridle arrangement for the kite that would produce the best angle of attack.

Students in my classes are varied in their backgrounds. Routine tests show double hump grade distributions. Despite this, one can educate each student to achieve his or her own optimum performance. "First just do it, then question the merits of the process and the product, and then devise criteria or excuses as to why and how it should have been done." This is the advice I give to those students who are skeptics at the outset.

The end of the school year is a hectic time for architecture students. Studio pressure, final tests in service and cognate courses, and sleepless nights all take their toll. Students were allowed to work at their own pace to complete this test and project, but they had to respect the deadline. All 49 students produced kites and attempted to lift an egg and to find out the minimum velocity of wind under which the kite would fly with the payload. Some of their kites were vastly oversized, but so what? All of them flew, and all were recorded in photographs.

Every course related to structural engineering in our school—the three required courses, and the elective courses in Experimental Structures, Fabric Structures, and Lightweight Structures—is geared to hands on experimentation in application of principles, whether the students realize it or not at the time of involvement. Even some faculty members are surprised to find creative projects being given outside the design studio context and environment. Atilla Bilgutay, Department of Architecture, SUNY Buffalo, Buffalo NY 14214.

An Editorial Note

The financial security of Connector is assured for the next few issues by an extension of the original grant under which it was founded. Substantial numbers of readers have written since the last issue to ask to remain on the mailing list. All this is good news. Less good is that in the months since publication of the previous issue, which was brimming with provocative letters and editorial matter, just four publishable letters have been received, and only one of these was written in direct response to material in that issue. This brings the fundamental premise of Connector, that there is a need for an informal forum on the teaching of architectural technology, into question. There seem to be plenty of us who like to read the publication, but at this particular moment, at least, not enough of us who are willing to venture an idea or opinion for publication in it.
Maybe We Should Just Join the Kids at the Beach

Dear Colleagues: I have what some of my friends consider rather odd ideas of what to research—roofing and concrete. I hear from the National Roofing Contractors’ Association that roofing is still not being taught in very many college architecture programs. Now I learn from the American Concrete Institute that concrete design and construction is not being taught in too many engineering colleges.

Since roofing is the part of the building responsible for the most litigation in building, I can think of no reason why it should not be taught at all schools of architecture. The old roofer says that the only two things a building has to do is stand up and protect the contents.

On the subject of standing up: Concrete is the most widely used construction material in the world...It is reasonably priced and extremely versatile. I guess what I’m trying to say is if we aren’t going to teach the kids how to make the building stand up or protect the contents, why bother? Maybe we should just join the kids at the beach and specialize in volleyball and beer drinking.

Luther J. Strange, Jr., Architecture Studies (ARC), University of Nevada, Las Vegas, 4505 S. Maryland Parkway, Las Vegas, NV 89154-4018

Integration of Technology and Design in Design Studios

With regard to integrating structures and building technology with the design studios, the question naturally arises: Why do we need integration? This can be answered as follows:

First, architecture encompasses all aspects of building design and construction. Therefore, an architect needs to develop a holistic approach towards design in which a "total building" concept is imperative. This warrants integration of structural, HVAC, lighting, and construction technology concepts with the architectural design process.

Second, architecture is a multidisciplinary field, and an architect has to interact with professionals of different disciplines. Integration will prepare the architecture students for such future interaction.

Third, architectural students often develop design concepts and solve attendant problems without realizing that the concepts could be developed by critically analyzing the engineering and technological aspects before the problems are solved. Prior to the industrial revolution when structural mechanics was not known to the architects and designers, they used to design buildings assuming the role of "master builders." They combined their structural intuition with architecture. In some cases they were even innovative from a structural design point of view and were therefore able to achieve buildings that had structural forms consistent with their architecture and that were safe and functional. They were able to critically develop the design problem. In a design studio, the same notion may be applied today so the students are trained in the a priori critical development of the design problem utilizing their basic instincts in all areas of design rather than merely in the solution of the problem.

Last, but not least, integration effort will make the students aware of the fact that time and money could be saved if they viewed the various stages of design as phases of an entire process. If the architectural design problem is formulated and solution achieved correctly the first time, probability of future design changes and modifications will be very low. This evidently will enhance the quality of design and reduce the cost of building construction.

Both the design and the structures/technology faculty must accept the fact that their disciplines complement and strengthen each other. Structures/technology faculty members could participate in design juries and review sessions as much as possible. It is desirable that these faculty members get involved in studio projects from the very beginning and guide the students in collaboration with the design faculty.

What are the benefits of integration? From a student’s point of view, the following benefits can be expected:

1. Students will appreciate the fact that building design is a comprehensive integrated process. The complexity of
this process will make them more sensitive to issues and improve their understanding of the overall design problem.

2. Students will develop a broad outlook about the diversified nature of design. Enlightenment in related disciplines will also increase their knowledge in other areas and hence make them better leaders.

3. Students will be conscious of the quality of design as well as resource and time constraints. This will increase their management skills and productivity.

From the faculty point of view, the following benefits are expected:

1. Faculty members in both design and structures/technology disciplines will rediscover that their areas of endeavor are very much intertwined. This will encourage collaboration between them as groups.

2. Structures/technology faculty can teach their own students the elements of architecture that are integrally related to the technical issues on the basis of their experience in dealing with architecture students in the design studios and the insight gained therefrom. This will enrich their classroom discussions. Likewise, architecture faculty may supplement their class lectures and the studio discussions with ideas brought in by their structures/technology counterparts and thus prepare their students better for a brave new world following their graduation. Mir M. Ali, School of Architecture, University of Illinois, Champaign IL 61820-6969. (reproduced with permission from 10/9/92 Rickernotes)

"...we should break from our emphasis on teaching and focus on student learning..."

Dear Colleagues: The continued dialogue on the issue of teaching technology as an integral component of the design studio or as a separate serve course is interesting. I have been extremely interested in this issue for some time, even using it as the subject of an article entitled "Integrating Technology Into the Architecture Curriculum," which was published in the Winter 1988 issue of JAE. However, I have recently changed my perspective somewhat and have switched from what might be considered an excessive concentration on teaching to a concern for student learning. Two events caused me to readjust my thinking.

Last year a student appealed a failing grade he had received in his design studio. I served as one of the faculty on the appeals committee. On the conclusion of our hearing, which indicated that the assigned grade was appropriate, the other faculty member on the committee asked, in a somewhat offhanded manner, "What are they teaching in the studio?" This comment intrigued me and caused me to question the educational intent of this traditional component of an architect's education. That is, does the studio provide us with a platform to teach or is it more an environment in which students can explore various issues and, through this exploration, learn? While there is an obvious connection between these two, I am not certain that we are always clear in how this connection is best achieved. Which brings me to the second event, which actually preceded this one and probably set me up.

Last Spring, I heard a report from a case worker who is employed by an organization for which I serve as a board member. This organization evaluates individuals with learning problems and attempts to provide recommendations for appropriate action. The case worker, again somewhat in an offhanded comment, indicated that in the case under review the teachers of the young student were trying very hard to provide help, but they seemed more intent on refining their teaching methods than on helping the student learn. I immediately had an image of the American who when trying to be understood in a foreign country talks English louder and slower, as if that will help someone comprehend a language they don't know.

Perhaps in our dialogue on teaching technology to architecture students we should break from our emphasis on teaching and focus on student learning. If we do this, we will come to recognize that both the studio and the service courses are necessary, for we need both to disseminate information to the students and provide opportunities for them to develop an understanding.

David Lee Smith, Department of Architecture, University of Cincinnati, Cincinnati, OH 45221-0016
Design in the Classroom is Not Far Fetched

Dear Colleagues: In the last issue, I especially enjoyed the comments of Irv Engel at Washington University on the subject of teaching principles. I also enjoyed the Satire Corner. Actually, the first bulleted item on teaching design entirely in the classroom is not so far fetched. I learned from John Habraken, when I was studying with him at M.I.T., that there is merit in this. I was his teaching assistant in his Thematic Design course, and in fact student exercises in designing were done in a classroom setting with excellent results.

This is not a trivial issue. Space is expensive in universities, and allocating so much square footage to each student for a dedicated work space is a luxury that may soon be difficult to justify...So learning to teach and study design in a different context is not a bad thing to be thinking about, in addition to such an activity being intellectually satisfying. Stephen Kendall, Marymount University, Arlington VA 22207.

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