Client Sponsored Research and Development in Construction Systems

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ABSTRACT

Building construction technology has always represented but a small part of the range of manufacturing processes in any time period. Potentially effective solutions to common or special problems within the building industry that are offered by standard techniques used in other manufacturing sectors are rarely applied in building construction. It is obvious that this limits the architect's design options if she does not intend to participate not only in the design of a building but in the design of the construction technology itself. In standard architectural practice the architect accepts these limitations and designs for normative building practice. A grant funded by the City of Raeford, N.C. made it possible for us to model and test new means for the construction of thin-shell vaulting for application in the execution of our design for a new performing arts pavilion constructed in the town center. A compound system of fiberglass and plywood, very common to boat-building, was identified as an appropriate technology for the stage's thin-shelled vault.

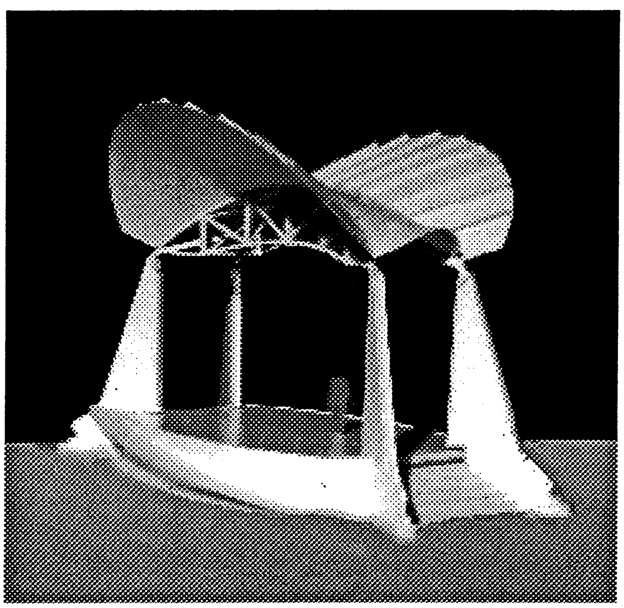

Fig. 1. Community Performing Arts Stage, Raeford, North Carolina

The research and development contract between the client and the architect made it possible to adapt this marine technology to the effective realization of the community-based project, and afforded an opportunity to show the applicability of advanced materials in a "low tech", craft-oriented process using inexpensive materials in a labor efficient manner.

PREVAILING CONDITION OF PRACTICE

It is held that common building practice is the constructional rule that defines architecture as autonomous, distinguishing it from other kinds of production.

Innovation, whether it be new technology or transfer of developed technology to architecture, does occur, however. In advanced technological cultures such as ours, this innovation tends to be limited to two distinct areas of building technology: the substitution of standardized mainstream components with new products, on the one hand, and radical reinvention of systems and components for highly specialized buildings of either great technical specificity or heroic symbolic purposes. But, it is relatively rare that the architect engages in desirable technological innovation which is architectonic and project specific in nature rather than component specific, and at the same time directed to the more modest budgets of the typical client.

It is not primarily as a matter of technology that this concerns me. It is primarily as a designer and from an aesthetic point of view that I am mindful of these limitations. I have no objection to a dominant normative practice in design and construction, and I am somewhat disposed to a favorable view of the autonomy argument. Still, there is reason to question the hegemony of such logic when, as at present, normative constructional procedures and structural patterns are no longer visually informative about relationships between forces and materials. It is this condition that renders the apparently level headed reasoning of Robert Venturi problematic:

Architecture may be ordinary —or rather, conventional—in two ways: in how it is constructed or in how *it is seen, that is, in its process or in its symbolism. To construct conventionally is to use ordinary materials and engineering, accepting the present and usual organization of the building industry and its financial structure and hoping to ensure fast, sound, and economical construction. This is good in the short run, and the short run is what our clients have largely retained us architects for. Architectural theories of the short run tend toward the idealization and generalization of expediency. Architecture for the long run requires creation, rather than adaptation, and response to advanced technology and sophisticated organization. It depends on sound research that may perhaps be promoted in the architects office but should be financed outside it, because the client's fee is not adequate for and not intended for that purpose. Although architects have not wished to recognize it, most architectural problems are of the expedient type, and the more architects become involved in social problems, the more this is true. In general the world cannot wait for the architect to build his or her utopia, and in the main the architect's concern should belong not with what ought to be built but with what is —and with how to help improve it now. This is a humbler role for architects than the Modern movement has wanted to accept; however, it is artistically a more promising one.*[2]

I would suggest that in its essential terms, Venturi's position remains in place as the dominant model of practice in this matter of our relationship to construction and innovation, regardless of superficial stylistic movements that would have us believe that anything has changed. And, his linguistic notion of architecture as a complex system of signs, rather than an immediate and direct experience remains problematic for us.

On the one hand, emerging research suggests that there is validity to the historically recurrent view that our very consciousness and our language are grounded in our long history of perceiving the world from an embodied terrestrial vantage point, a reference point which we universally share. On the other hand that reference point is no longer reified by the built environment. If we are removing ourselves from such grounding referents, then with what will we supplant them, cyberspace? Is it promising to settle for unmoored intellectual maneuvers whose meanings are *attributed to* rather than *lodged within* objects (having meanings as opposed to being meaningful)?

A reasonable position on this matter is that it is a directness of experience rather than an indirect "intertextuality" that distinguishes architecture from rather than connects it to language, literature, or rhetoric; connections about which so much fuss has been made. While so much effort has been made to produce a "textual" architecture, the evidence suggests that architecture is less well equipped for carrying messages and more well equipped for being the tangible experience upon which language may ground itself. In spite of that fact, contemporary architecture continues to become less substantial and increasingly referential.

Looking back for a divergent tendency we see that the brutalist monumentalization of the constructional aspect of building was an easy target for Venturi's attack. But, on the other hand, the present situation in which the lack of craftsmanship of the hidden frame is irrelevant to the finished appearance of our work saps meaningfulness from our activity, not to mention the activity of those who build our designs. Structure and construction in and of themselves can not support a meaningful way of building, yet, when they are no longer integrally important to the way the building is both conceived and experienced, as literal, not merely allusive conditions, building can not be a meaningful activity.

ALTERED CONDITIONS FOR THE PROJECT

The City of Raeford North Carolina approached us with a request for a design for a festival pavilion for their downtown park. Specifically, the project had been initiated by the directors of the North Carolina Turkey Festival, an annual event that promotes the community's primary industry. Going into its ninth year the festival had worn out its demountable tent-roofed stage and the directors looked toward the tenth year as a benchmark for establishing a permanent architecture. The Festival Committee quickly organized the participation of all major community entities and established support for a permanent performing arts stage to serve year-round community events. The College was contacted and I began working with the community committee in June 1993.

When I presented this model to the Raeford group in August 1993, it was my intention to limit evaluation to the overall form, siting, and orientation, so I set aside numerous considerations I had made about materiality and construction as a topic to follow scheme approval. Although I did get as specific as showing a substantial truss element with ribs suggestively branching from it to support the wings, the gesture was intended only to give a sense of scale and general structural order. I advised the group not to consider such elements literally, pointing out that there would be a range of possible material systems for developing the scheme, and that each one would substantially influence the detail.

Once the scheme was approved, my first object was to put together a interim set of details for estimating so that a target figure for fund raising could be set. It was rather clear to me given the modest circumstances of the town itself that a stated upper limit of $70,000.00 had to be respected; and furthermore, given the scale of the project and my added concern about the many other needs of this, one of the state's poorest counties, that I would be more comfortable with an unstated target of $40,000.00. The estimating set proposed a steel skeletal structure with the planes of the roof non-structural in modest agricultural galvanized steel sheathing. The more material choice was to be offset by the repetition of like elements and the use of standardized steel sections and off-the-shelf roofing. Furthermore, the community was confident that a local steel fabricator of high quality would make the components at cost.

My goal was to submit for estimate a relatively high-end version materially, but cleanly detailed in the effort to hit the $70,000.00 target. I felt that if we could get that far, we could start over with the design development, knowing at least that the funding target would support one reasonable version. That version, did however contain a major compromise, the use of standard steel sections, where the flow of the form suggested that developed as a skeleton, the shape of linear elements should be more refined.

The plan was submitted to an estimator who worked with a local architecture firm and the estimate came in at $115,000.00. The steel alone was priced at $36,000.00 for labor and materials, without considering its provision at cost, but needless to say, it was rather obvious that such minor adjustments would only dent a grossly padded estimate. What became most clear in the estimate was an experienced estimator's opinion that the local trades would treat the project as a highly specialized custom project, regardless of the simplicity of the detailing, simply because its overall form was unfamiliar.

It became clear to me that if I was committed to the idea, I would have to abandon the notion of turning the construction over to a contractor, and handle it myself. I also concluded that given the dramatically high estimate, I would have to seek the most efficient structural system in terms of material cost. While that directed me immediately away from a skeletal structure toward a thin shell. I also sought to maximize the extent of the job that could be done within the College's workshop and construction yard so that we would not have to travel frequently to Raeford which is over two hours from our campus. Resolved to abandon the constraints of normal constructional processes, I then had available to me any constructional system that I could find the wherewithal to execute.

A grant supplied by the Raeford fund raising committee made it possible for us to model and test alternative means for the construction of thin-shell vaulting for application in the execution of the design. Normally, such a materially minimal and lightweight compressive structure would be executed in steel or in concrete. The former is costly in terms

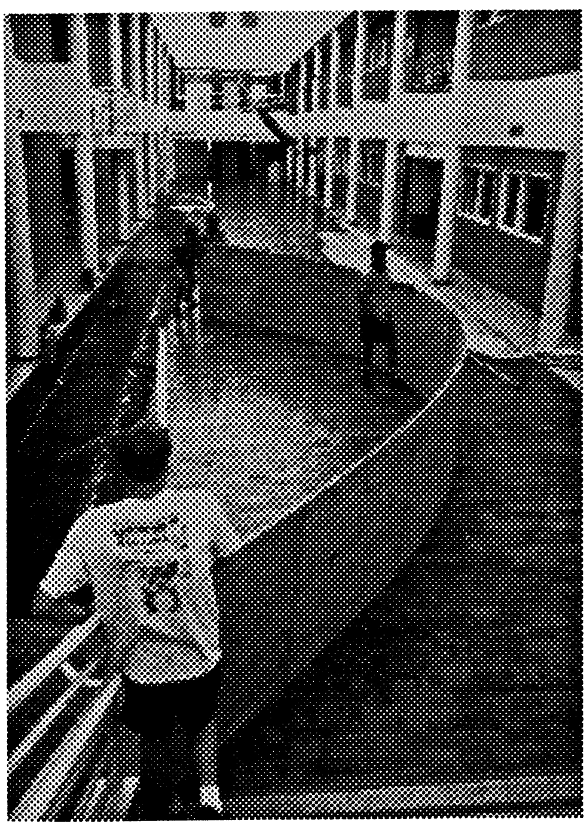

Fig. 2. A series of full scale plywood cross-sections were constructed and tested to failure for selection of proper plywood type, thickness and orientation; and for examination of scarf joint dimension, epoxy specifications and application, and quality control of joining sequence. Quality assurance in the epoxy joints proved as critical a procedural issue as material specification.

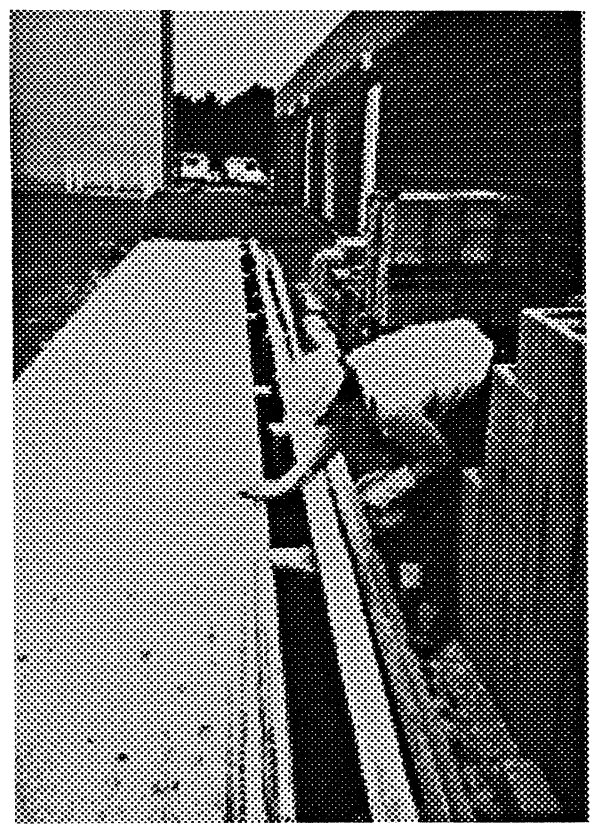

Fig. 3. Following the selection of 4-ply, 5/8" A/C plywood and development of a moderately efficient process for cutting 3-inch wide bevels along edges to be joined, 4'-0" by 40'-0" panels were mass-produced. After assembly of 40-foot panels, long edges were beveled and epoxy applied.

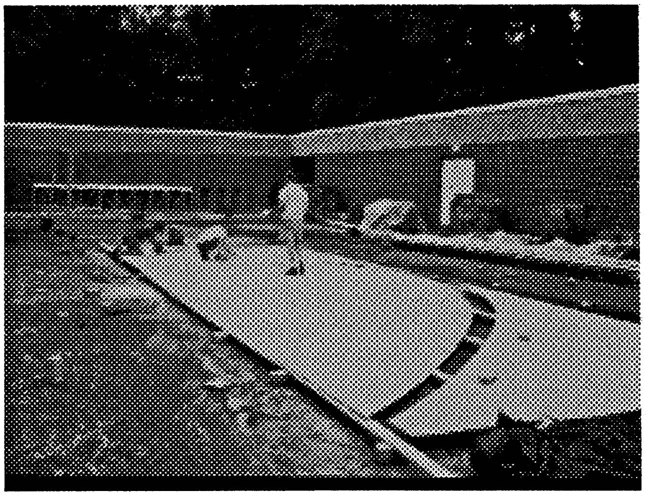

Fig. 4. Four 40-foot panels were joined to make each cantilever vault. 50 foot long 1x3's already epoxied together were screwed together from opposite faces of the joints to provide continuous clamping during curing. The 1x3's were then used as the layers for the the glue laminated beams. Each of the two 40 x 16 foot sheets of joined plywood were cut to the parabolic shape of the flattened cantilever vaults. Scrap material was used for the center section between cantilever vaults.

Fig. 5. Beams could be laminated very quickly with screws to clamp epoxied layers. Few clamps were used with minimum pressure to hold layers for screwing while allowing longitudinal slippage as screws were placed from the center outward toward the ends. Each layer was offset slightly from the previous to establish a beam face vertical in its final rotated position and normal to the steel connectors atop the concrete block pier.

of materials, while the latter is costly in terms of formwork and labor. The modest budget of this community sponsored project permitted neither. In funding the grant, the city recognized that the investment in research and development would reduce the ultimate cost of the project. With several options for lightweight wooden structures in mind, I was able to confidently offer a figure of $60,000.00, half the estimated price. For us as architects this meant the freedom to redefine construction process in service to full realization of design intentions.

Looking for cost-effective alternatives, a compound system of fiberglass and plywood, very common to boat-building, was identified as an appropriate technology for the stage's thin-shelled vault. However, because it is a transferred technology, it does not lend itself to standard project contracting. The techniques to be applied would be considered a costly custom job to a building contractor, and the untypical land-based forms required would be contracted equally dearly from a boat builder. The research and development contract between the client and the architect made it possible to adapt this marine technology to the effective realization of the community-based project, and afforded an opportunity to show the applicability of advanced materials in a "low tech", craft-oriented process to the production of advanced design concepts, using inexpensive materials in a labor efficient manner.

The 26 x 36 foot plywood and fiberglass structure was developed at the College of Architecture with the participation of skilled student craftspeople and the oversight of construction lab staff and one of our structures professors. The core of the student team was paid through the grant, though others volunteered their time out of interest in the project. The structure was developed through a series of large scale models investigating structural properties and construction sequences. Among the outcomes of this process was the elimination of the need for formwork for the fabrication of shell elements and the optimization of structural sections through empirical calibration. Fabricated in three separate sections at the College of Architecture, the roof was erected on the concrete block buttresses in Raeford in August. The total cost of the roof was $16,000.00 and the total cost of the project including the stage and base in approximately $40,000.00. Of the ten week construction time we spent only two weekends and one week on-site.

DESIGN/BUILD PROCEDURES

The design development and construction sequence follows. Brief general conclusions will be addressed afterwards. It should be pointed out that other than the working drawings for the base we made almost no drawings other than sketches to work out critical dimensions. With physical, temporal and psychological immediacy of construction it always made more sense to use educated trial and error rather than graphic prediction of essentially non-graphic issues. We applied this procedure at increasing scales of modeling, in full-scale mock-ups and tests, and throughout the fabrication of the final product. With a general confidence in the soundness of the overall concept we were comfortable leaving unresolved questions to later moments when more physical presence of impinging conditions would inform solutions. As a result design and constructional questions became indistinguishable, the resolution of geometric complexity became the source of inherent ornament, ornament that could not have been prefigured as a purely formal invention, and a general pragmatism tending toward a "path of least resistance"

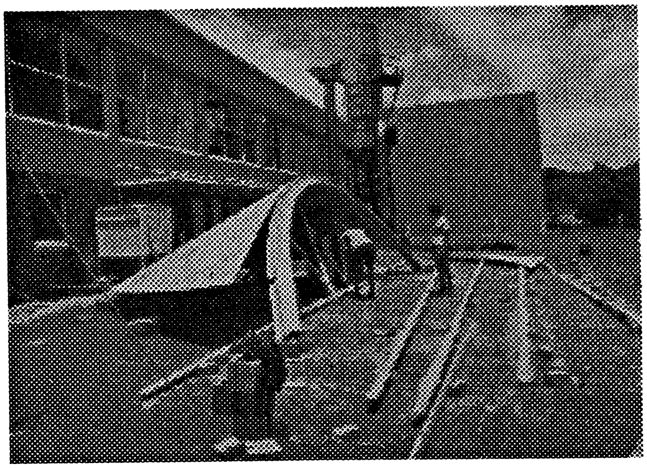

Fig. 6. Finished beams spring back about one foot when released from formwork. For assembly they were pretensioned back to desired curvature with steel cable which was removed after the roof was restrained by the permanent pin connections atop the piers. Finished beams were used as forms for curvature of vaults. Preassembly off-site continued from this point without epoxy to permit dismantling and shipment of elements to site. Vaults were removed from beams for flat shipping.

approach enriched and refined rather than depleted the formal concept. (insert Figures 2-10 here)

CONCLUSIONS

Much of what we ended up accomplishing was unplanned. It had been my initial intention only to demonstrate the compatibility of simple (rather than tortured) structural expression, ritual and economy of means. As it turned out the last of these goals required that I transform my assumptions about construction process. This transformation was multivalent. Most obviously I moved from being only the designer to being part construction manager and part apprentice craftsperson. Furthermore the nature of the design changed from being based upon norms of construction to being the invention and adaptation of the alternative construction process. As a result the sequence allowed design and fabrication to be concurrent so that construction and design decisions merged.

Perhaps the least evident effect of the above transformations was that the individual roles of all participants became complex, creative and non-hierarchical. Because the design literally reinvented itself in the shop, everyone was present at the creation and operated with a sense of ownership. This made the effort not only extremely pleasurable but imparted to the final object a kind of frankness that reflects the balance of design ideals and reasonable practices. This result rejects the notion that it is a matter of architectural responsibility to hold the line of purely aesthetic or symbolic aims against the encroachment of constructional expediency. It posits instead the notion that the process itself has an inherently aesthetic aspect which contributes to the outcome in a legible way. Having stumbled upon the actuality of this experience which is so often presented as a mere medieval nostalgia for the craft experience it will be difficult for me to continue to value very highly any design and construction process which does not allow this to occur.

Additionally, and contrary to Venturi's position presented earlier, in being forced by circumstance to abandon conventional constructional means, I discovered that by intervening in the constructional system one can also demystify building. Treated as a matter of informed sensibility and reasonable technical awareness design can transform the building process without upsetting the laws of nature. Conceptually the renewal of constructional systems strengthens the designer's grasp of building, whereas the acceptance of standard procedures relinquishes not only participation but meaningful authority. It does this because it eliminates the crutch of external authority and adopts a confidence in one's own intelligence, and the willingness to test it.

It should also be noted that in returning to the root of the

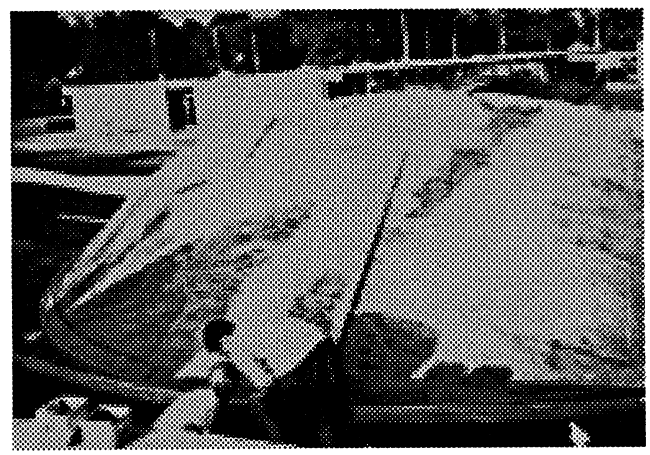

Fig. 7. Laminated attachment of edge bead. Edge beads serve as stiffeners and gutters to channel water to valleys at pier connection.

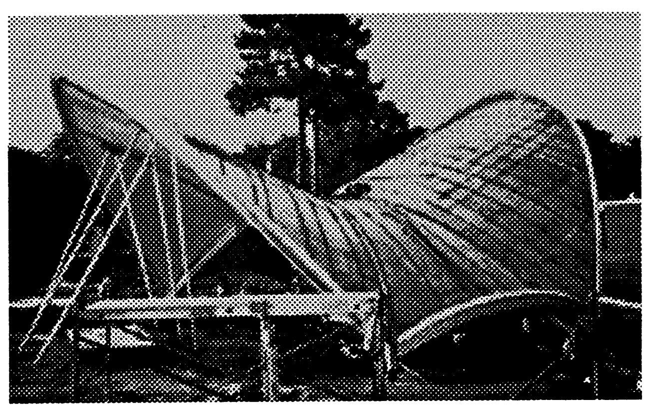

Fig. 8. Completion of lateral entry vaults and placement of rebar for casting of 2" lightweight concrete shell. The concrete was not needed for gravity or normal wind loads, but was added as dead weight as a precaution for unpredictably high wind. Conceived for weight, the concrete shell was made structurally integral by securing rebar to plywood vault with screw eyes and by welding bars at the vault edges and in the valleys directly to steel beam connector plates to transfer some concrete load directly to piers.

construction process we stopped short of redefining the materials used. We did not assume in our low-tech approach to innovation that existing systems use existing materials optimally, but that an new synthesis of materials evolving within separate constructional systems might better apply the capacities of those materials. As a case in point, our use of plywood as structural shell makes use of its combination of flexibility and fibrous strength that is undeveloped in its most typical sheathing and shear panel applications which only acknowledge plywood's more limited planar rigidity .

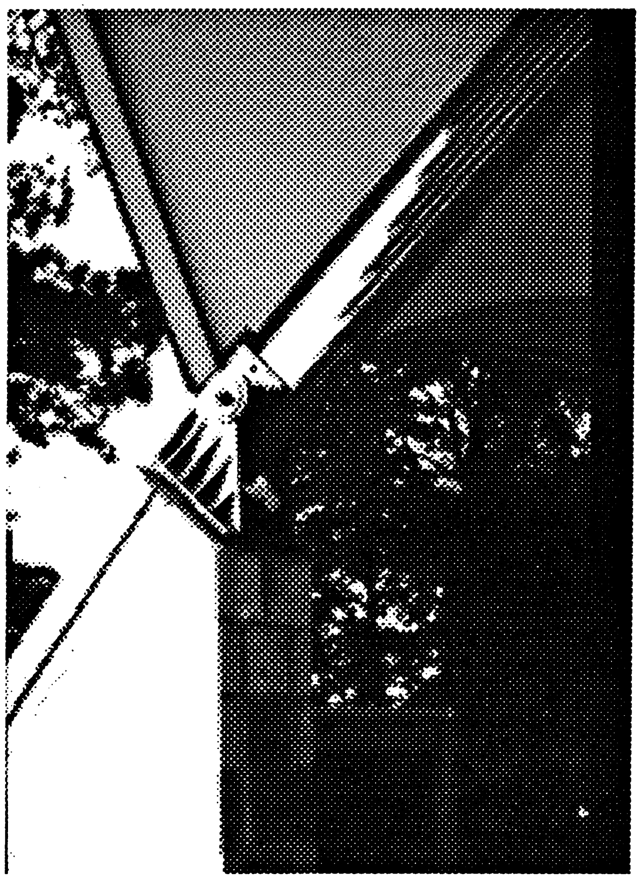

Fig. 9. Typical assembly at intersection of vaults, beam and pier. Steel pin connector is 2-inch diameter, and bolting plate on beam face penetrates vault to become a scupper above for channeling rainwater from valleys to a trough cast along the top of the sloping pier.

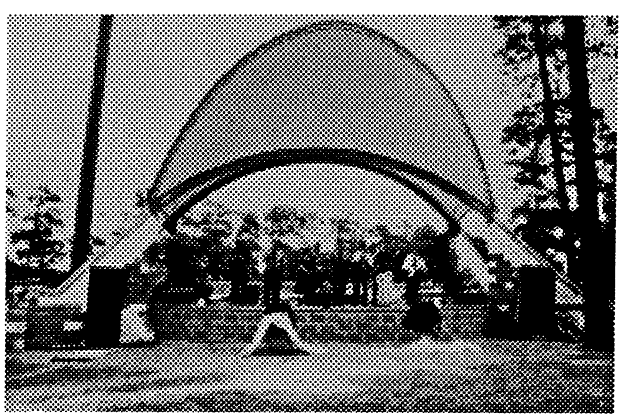

Fig. 10. Completed stage in use.

Much of Venturi's complaint stemmed from the tendency of modern tinkering with building technology to place the architect in the unwieldy position of revising the manufacturing industry. By contrast, our objective, simply for the sake of economy and transferability was to accept and invent with the standard products of industry. Our discussions on this matter have led us to conclude that technical innovation of this sort makes sense as a shorter time frame of modest invention that builds up to longer scale transformation in the industry. It would appear that Venturi over-reacted instead of fully evaluating the fine grain of the general evil he condemned. But then we should not be surprised, since his comments in reasonable construction practices were not motivated by an interest in construction, but as a justification for a non-literal architecture; a linguistic rather than tectonic concern. Since his rhetoric obscured this distinction, the impact of the treatise on the dominant view of the architect's influence over construction process has, in the end, had more long-lived impact than his formal objectives.

I realize that our project was small in scope and free from the business constraints of either the full-time professional office or contracting firm. During the process we had many discussions about the implications of these facts for our desire to continue practices which we came to value. I will reserve discussion of this and other concerns for the dialogue to follow.

PROJECT CREDITS

Roof Design/Build Team: Jim Asbel, Ian Rutherfurd, Jack Barnes, Trisha Vaughan, Taylor Lawson, Tom Dolan, Belinda Curren.

Stage and Pier construction: Mike McNeill, Director of Public Works, Raeford, NC; Lynne Worley, Project Manager; Bobby Strother, superintendent, Leland Strother; surveyor.

Project Engineer: Charles Mitchell, PEAcknowledgements: Rich Preiss, Phil Gaddy; UNC-Charlotte COA Construction LabsMichelle Price, UNC-Charlotte Purchasing Office Burlington Industries, Raeford, NC, Steel fabrication Johnson Concrete Company, Raeford, NC, Concrete Block

NOTES

1 Tom Schmacher, "The Skull and the Mask", *Cornell Journal of Architecture*, Rizzoli International Publications, New York, 1988, no. 3, pp.4-11.

2 Robert Venturi, Denise Scott-Brown and Stephen Izenour, "Theory of Ordinary and Ugly and Related and Contrary Theories," *Learning from Las Vegas*, The MIT Press, Cambridge, Mass. 1977, pp. 128-129.

3 Julian Jaynes, "Chapter 2: Consciousness", *The Origin of Consciousness in the Breakdown of the Bicameral Mind*, Houghton Mifflin, Boston, 1976. Pp. 48-66.

4 Mark C. Johnson, *The Body in the Mind*, University of Chicago Press, Chicago, 1987.