The Southern Idaho Section

of the

American Society of Civil Engineers

presents

BARREL ARCH ROOF FOR UNIVERSITY OF IDAHO STADIUM

as a nominee for the

OUTSTANDING CIVIL ENGINEERING ACHIEVEMENT AWARD - 1976

Boise, Idaho

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CONTENTS

BARREL ARCH ROOF FOR UNIVERSITY OF IDAHO STADIUM

INTRODUCTION

The new William H. Kibbie - ASUI Activity Center at the University of Idaho, locally called the "Kibbie Dome", will be the first of its kind in the world to use a lightweight composite wood and steel roof system.

At Moscow, Idaho, the location of the University, the mean annual precipitation is 22.21 inches, of which about 28 percent occurs during the football season. Over the years since 1893, when the first football game was played, both participants and spectators have had to endure inclement weather at many contests. Also, practice time for the players has often been severely limited by wet weather. Northern Idaho is in the path of prevailing westerly winds often of high velocity. In addition to rain and snow, these winds contribute to discomfort at outdoor events in the area.

As part of a program to upgrade the entire athletic program at the University of Idaho, officials decided to replace the aging wooden Neale football stadium with a modern multipurpose structure. To provide a facility that would be suitable for many kinds of events in addition to football and other athletic activities, it was planned to enclose the entire game and spectator area with a roof and end walls.

The new stadium was built in three phases: (1) substructure; (2) artificial playing surface; and (3) roof and end walls. Work began in 1969 and the first two phases were completed in 1972. Phase 1 of the project provided a concrete substructure with a seating capacity for football of 21,000 at present and 26,000 in the future when seats are added at the ends of the stadium. Phase 2 of the project consisted of furnishing a playing surface manufactured by 3M Corporation of Minnesota which can be removed from the field for events other than football, soccer, etc., by rolling it up on an 8-foot diameter drum which is stored against the west end wall of the stadium. This is the world's first portable artificial surface to be placed on a football field.

DESIGN

The principal design firm for the enclosed stadium was Cline, Smull, Hamill, Associates, Chartered, of Boise, Idaho. Consulting engineers were: (1) Cornell, Howland, Hayes, and Merryfield, Boise, Idaho, for soils, foundations, and structural considerations; (2) Engineering, Incorporated, Boise, Idaho, for mechanical and electrical features; and (3) Bolt, Beranek & Newman, Incorporated, San Francisco, California, for acoustical and sound systems.

The uniqueness of the problem of covering the new stadium with a roof 400 feet long and with a clear span also of 400 feet for a cost within limits imposed by the athletic budget, prompted the design team to solicit ideas from the construction industry. Accordingly, for phase 3 of the project, design studies included requesting preliminary proposals from firms experienced in the design and construction of roof systems.

The problem as described to these firms was to "design and construct a stadium roof with a clear space of 400 feet and a vertical clearance above the playing field of 150 feet conforming to all loading, deflection, material, geometry, temperature, drainage, and other criteria as specified".

Requests for proposals were made to eleven firms and, of these, nine submitted preliminary proposals as follows:

1. Behlen Manufacturing Company of Columbus, Nebraska, submitted a steel roof arch system.
2. Butler Manufacturing Company of Grandview, Missouri, submitted a steel roof called the "Triodetic Arch System".
3. Birdair Structures, Incorporated of Buffalo, New York, submitted an air-supported roof system.
4. Pascoe Steel Corporation of Pomona, California, gave a proposal for a steel arch roof system.
5. Timber Structures, Incorporated of Portland, Oregon, proposed trussed timber arches with trussed timber purlins.
6. Sargent Industries of San Francisco, California, submitted an air-supported system with suspended glu-lam components from which to suspend lighting and ventilating equipment.

7. Uni-tensile Corporation of Salt Lake City, Utah, proposed a system of plastic pyramids so shaped that when strung on cables they formed an arched roof. The addition of a horizontal cable at the bottom resulted in a tied arch system.
8. Trus Joist Corporation of Boise, Idaho, proposed a system of glu-lam trussed arches.
9. Tim-Fab, Incorporated of Clackamas, Oregon, submitted wooden trussed arches with wooden trussed purlins.

After reviewing the above proposals, some of which were quite new and unique, it became apparent that the design and construction phases of the roof system would likely have more than ordinary dependence on each other. Therefore, it was decided to have the roof system built using a design-construct type of contract.

TRUS DEK ROOF SYSTEM

The description of the work in the specifications accompanying the bid documents stated that "The intent of this specification, with related drawings and other information, is to provide a roof and end-wall enclosure system for the existing New Idaho Stadium, including all construction required from the top of the existing supporting concrete walls, piers, beams and transfer beams as designated on the drawings, the roof structure spanning over the existing stadium space, and including all acoustical and other ceiling systems, roof structural system, roof vapor barrier, thermal insulation, waterproof surfacing, end-wall trusses, insulated and weatherproofed end-walls, flashings, sealants, finishes, accomodations for loadings and support capabilities for catwalks, platforms, ladders, mechanical, electrical and sound systems. The construction shall comply with all applicable codes and regulations and shall be in accordance with structural and design criteria as shown on the drawings and as hereinafter specified. Such work shall be designed and constructed by the contractor working in close coordination with all subcontractors and other involved parties under the prime contractor to whom the contract is awarded, all to provide a completely weatherproof, structurally sound and esthetically acceptable system."

Bids were received from two firms, Vern W. Johnson & Sons, Incorporated, of Spokane, Washington, and Emerick Construction Company of Portland, Oregon. Both involved proposals for glu-lam type roof structures. No bids were received for steel roof systems perhaps because at the time the price of steel was exceptionally high and it was in short supply.

In accordance with the instructions to bidders, a review of the proposals was made by an evaluation team composed of representatives of the University and the design consultants for the project.

Among the factors considered, in addition to bid prices, were the compatability of the proposed "design/construct" roof and end walls with the existing stadium concept and structure, esthetic appearance, durability of materials and products, life-cycle cost considerations, commitment of the bidder to meet the specified construction schedule, etc. It was stated that the award could be made to other than the low bidder.

It was the recommendation of the evaluation team that the University's interests would be best served by awarding the contract to the Emerick Construction Company.

The principal supplier for Emerick Construction Company was the Trus Joist Corporation of Boise, Idaho. This firm, which has pioneered in the design and use of wood and combination wood and steel joists, was responsible for designing and furnishing the roof and end-wall systems. KKBNA, structural engineers of Denver, Colorado, proved the design concept, determined stresses, and sized the members.

The roof system, a new and unique development by the Trus Joist Corporation, consists of a 400-foot clear span barrel vault type roof enclosure, approximately 7 foot - 8 inches deep, known as Micro-Lam/Trus Dek. The end walls consist of 54-inch deep conventional Trus Joist TJM and TJH trusses set vertically on concrete end-wall supports at 4-foot centers.

The Micro-Lam/Trus Dek is made up of an upper and lower wood deck connected by steel tube web members forming in essence a two-hinged trussed arch. The arch elements are supported on transfer beams which are a part of the stadium concrete substructure. The upper and lower wood decks consist of Micro-Lam which is a specially laminated lumber made of sheets of veneer glued into billets 24 inches wide and 1 7/8 inches thick. The trussed arches, made up of an upper and lower Micro-Lam billet connected by the steel tube web members, were placed side-by-side to form a continuous wood deck for the roof and ceiling.

The Micro-Lam billets were cut into 80-foot lengths and pre-drilled for splice plates and clip connections with a tolerance of only 1/32 inch. More than 35,000 web members of cold-rolled galvanized steel tubing were punched on a special die with a length tolerance of 0.005 inch. Sizes of tubing range from 2 inch - 16 gauge to 2 1/4 inch - 13 gauge, depending upon the stress areas.

Because the roof arch moves slightly in both vertical and horizontal directions under different load conditions, a special teflon-coated slip joint bearing connection was designed for the point where the arch connects to the end wall.

A key to the roof system is Micro-Lam lumber, which is a recent development by Trus Joist Corporation of a slightly densified laminated veneer billet. Micro-Lam is manufactured in a continuous press with a lay-up of standard 27-inch by 101-inch veneers end jointed by staggered lap splices. The depth of the billet is variable with the width trimmed to approximately 24 inches and its length is continuous. The wood grain of all the veneers runs parallel with the length. The adhesive, a phenol formaldehyde, is spread totally on one side of each mating veneer. Press rate and temperature are controlled to establish densification and a cure for the glue.

Micro-Lam billets are made up of 1/8 inch C - D grade veneers with clear A - B grade veneers for outer skins. All veneers are of a Douglas fir supplied from the Eugene, Oregon area. Glue spread, press speed and temperature are controlled to a close tolerance. The degree of densification is 8 percent away from laps and 25 percent at laps.

CONSTRUCTION

Emerick Construction Company subcontracted erection of the roof and end-wall systems to MacGregor Triangle Company of Boise, Idaho. Grays Crane and Rigging Company of Portland, Oregon, provided the cranes and rigging.

The stadium site posed some work-area restrictions on the assembly and erection of the Trus Dek components. The work area consisted of an adjacent playing field at one end and a parking lot at the other end. Because the stadium is situated in a trough between two hills, the work area was limited to the two ends of the building.

No preassembly was done at the fabrication plants prior to shipment of the Trus Dek components; all assembly work was done at the jobsite.

Assembly and erection of the Trus Dek components was done in three steps: (1) sections 80-feet long, consisting of six 24-inch Micro-Lam billets laid side by side, were assembled on jigs curved to the arch configuration (243.18-foot radius to the bottom of the ceiling billet); (2) the 80-foot-long sections were moved to a larger scaffold where three of them were connected to form a half arch, and anchor components were attached to one end; and (3) the two half arches were lifted by cranes and connected in the air at the crown to form a complete arch section 12 feet - 5 inches wide.

The pairs of angles for connecting the webs to the billets were secured to the billets with countersunk bolts and the web members were connected to the angles with 5/8 inch pins.

The assembled half arches were rolled sideways across the work area in assembly-line fashion. Each half was assembled in reverse direction to the previous half so that ends and center joints would match for final handling and placement. A 12 foot - 5 inch section of the continuous steel bearing support truss, which was fabricated in Spokane, Washington, was attached at the support end of each half arch. Each half arch weighed about 23 tons.

The half arches were walked into position by a 200-ton Lorain truck crane with a 210-foot boom and a 140-ton Manitowoc crane with a 190-foot boom. Each half arch was pinned at the transfer beam and the load at the other end was transferred to a 30-ton GCI tower crane with a 140-foot tower and an 80-foot boom. The two mobile cranes then returned to the scaffolding, picked up the second half arch and walked it into position. When the working area became more confined as the roof neared completion, two smaller cranes were added.

CONSTRUCTION - Continued

When the two half arches were in place, they were slowly lowered until the two ends at the center fit together after which they were secured with a steel plate. Ninety-one bolts were dropped through pre-drilled holes in the Micro-Lam to connect the new arch to the adjacent arch at each panel point. Only the ability to maintain close tolerances during the manufacturing process made this possible.

While the roof arches were being erected, the end-walls were assembled into 16-foot panels or sections on the ground. Wall covering materials were nailed into place before erection of the wall units. Upon completion of the roof, the end-wall units were hinged to the end-wall support beams and attached to the end-wall truss.

Roofing consists of 3/8-inch plywood sheets layed diagonally and covered with 1 1/8 inches of sprayed-on urethane, a layer of foam insulation, and a 28-mil film of monogram elastomeric roofing material. Lighting is suspended from the two catwalks that run the length of the field.

An acoustical ceiling consisting of 12-foot by 12-foot panels made up of 4-foot by 4-foot lay-in type sound absorbing material is suspended over the entire area of the stadium.

The sound system consists of multiple sound clusters suspended from the deck system over the playing field and seating area. Dividing nets may be raised and lowered to divide the field into small areas for tennis or basketball. The 7 1/2-foot space between the top and bottom Micro-Lam billets is also used as a mechanical plenum.

The interior finish for the end walls consist of horizontal 1-inch by 4-inch battens closely spaced for esthetical and acoustical purposes. The exterior finish consists of 3/4-inch tongue and groove plywood nailed directly to the chord members. Vertical 2-inch by 4-inch battens are nailed over the plywood joints at 8-foot centers. Thermal and sound absorbing insulation is located inside of the end-wall sections. Provision has been made to remove sections of the end walls to add end-zone seating in the future.

Other principal suppliers for phase 3 of the stadium included:

1. Seattle plant of Bethlehem Steel Corporation - furnishing pins to connect webs to the connection angles and bolts for attaching the connection angles to the Micro-Lam billets
2. Gale Mechanical of Spokane, Washington - furnishing and installing mechanical equipment
3. Electric Smith of Spokane, Washington - furnishing and installing electrical equipment

CONCLUSIONS

Contribution to the well-being of people and communities

With completion of the new William H. Kibbie - ASUI Activity Center, the students and people of northern Idaho and eastern Washington will be provided not only with an all-weather athletic field for football, soccer, indoor track, basketball, tennis, volleyball, baseball practice, golf practice, wrestling, boxing, and intramural sports, but also with an excellent facility for band and drill team practices and events, commencement and large audience events such as "rock" concerts, circuses, carnivals, exhibits, road and trade shows, extra large catered banquets, dances, rallies, conventions, etc. With the use of new artificial ice surfaces, the Center will accommodate ice skating, hockey, ice follies, etc.

According to the University of Idaho athletic director, "Multipurpose, as a concept, is very much the coming thing. It means using one large structure for all kinds of sports and non-sports events. Basically, its a matter of economics. With land getting expensive and scarce, and construction costs sky-rocketing, schools can no longer afford single-purpose structures. Most stadiums of the future, I'm sure, will be built with multi-purpose use in mind. New synthetic surfaces, characterized by their resilience, toughness and durability, make multi-purpose use possible."

Dr. Ernest W. Hartung, President of the University of Idaho, says that, "Our completely redone athletic complex, centered around the covered stadium, will be a tremendous asset not only to the University but to the region - for participants and spectators alike. We feel that the new Kibbie - ASUI Dome will be in constant use whether for intramurals, individual exercise, varsity sports or for concerts, convocations and conventions."

The entertainment director for the Associated Students University of Idaho, exhibiting youthful enthusiasm, believes Moscow has the potential of becoming a major entertainment center of the Pacific Northwest. He claims, after conducting research, that Idaho has the largest indoor college concert facility in the country, and the fifth largest overall. It is estimated that gross ticket sales for concerts could easily double those of football and basketball combined. A major national act could attract fans from as far east as Missoula, Montana; from southern Idaho; the Spokane, Washington area; and the Tri-cities area of Washington.

The merits of the project, including design and construction innovations as well as benefits to the local community and to the region, were widely acclaimed in local and national newpapers and professional and trade magazines.

Resourcefulness in planning and in solution of design problems

The design and construction of the stadium roof and end walls involved more than the usual amount of team work between engineers of various disciplines and construction people. The use of a design-construct contract was unique for a structure of this type. Usually such structures are designed by a design firm and then a contract is let for construction of the structure in accordance with the drawings and specifications, an arrangement in which the contractor has nothing to do with design of the structure.

By soliciting preliminary proposals during the design stage, the architects for the project were able to obtain ideas for new and in some cases untried roof systems that offered economical and sound solutions to one of the most challenging projects ever to confront a design-construction team--completely enclose an entire football stadium.

The roof system required approximately 2300 Micro-Lam billets, each 80-feet long, representing about one million board feet of lumber, 57 miles of tubular steel, over 35,000 steel pins, and 71,000 bolts. The reaction of the arch is uniformly distributed across a light weight, continuous beam through 192 pin assemblies located along the top of the stadium walls.

The ceiling has a total of 798 sections of acoustical panels suspended 4 feet from the inside of the roof, covering the heating and air-conditioning ducts. The stadium's unique design features sound-deadening surfaces other than the acoustical panels. The 1-inch by 4-inch battens on the end walls allow absorption of sound and the Micro-Lam billets of the ceiling, above the panels, allow movement of air and sound between them and the sound is reflected back into the upper sides of the "clouds" of acoustical panels. The 24-inch wide Micro-Lam billets are separated by 1-inch spaces for the web connections, gaps that serve as exhaust vents in the ceiling at the lower face, while the open-webbed arches serve as return-air plenums.

A special problem resulting from the effects of wind was anticipated along the top of the arch roof at the ends of the stadium. Wind-tunnel studies made at Purdue University showed a considerable increase in negative pressures with high velocities over the square edge at the ends of the roof. Because, economically, there could be no local variance in the resistive properties of the roof system, the use of these high local pressures for design would have required reinforcement of the entire roof. As a result of this study, a large box-like structure 8 feet deep and 3 feet - 6 inches wide called a "wind spoiler" was incorporated into each end wall in such a manner that its top projects 1 foot - 6 inches above the top of the roof arch.

Pioneering in the use of materials and methods

Although Micro-Lam is made up primarily of relatively low grades of veneer, the reworking of the material and random dispersement of natural defects results in a high-strength material having a coefficient of variation less than half that of sawed lumber. By manufacturing Micro-Lam lumber so that the wood grain of all veneers runs parallel with the length, the flexural strength of a Micro-Lam billet is considerably greater than that of a billet of comparable size made of conventional plywood. Typically, the resistive moment of a 1 1/2-inch by 12-inch Micro-Lam joist is 1.79 times greater than the resistive moment of a No. 1 grade 2-inch by 12-inch Douglas fir-larch joist.

In addition to its strength and reliability characteristics, Micro-Lam has very consistent moisture content and thus its dimensional stability is excellent. It resists warp, check, or split. It has the same advantages as sawed lumber being nailable, glueable, sawable, and has a high strength/weight ratio.

Micro-Lam utilizes veneers obtained by roll cutting of the log for approximately 20 percent greater fiber recovery when compared with sawed lumber. The log can be relatively low grade, because defects in the several veneers are randomly distributed so that the resulting strength of a Micro-Lam billet is comparable with the highest grades of sawed lumber. As availability of high grade logs diminishes, upgrading of the basic material by recovery of more fibers and reworking for higher strength becomes an economic advantage and a factor in the conservation of natural resources.

Innovation in construction

The contract completion date, which was set so that the covered stadium would be ready for the first football game in the fall of 1975, resulted in an unusually short period of time available to the contractor. Nevertheless, the work was so well organized that the total roof erection took only 30 calendar days, and assembly preceded erection by only two weeks. This was done under almost continuously inclement weather conditions, in a limited work space, and mostly by inexperienced crews, and yet the project was completed on time. In general, the erection went like clockwork with a minimum of delays and unperceived problems.

Two factors were largely responsible for the speed and smoothness attained in erection of the roof arches and end-wall sections. First, the general concept of the Trus Dek arch roof system with its 2-foot wide laminated wood and steel truss modules lent itself admirably to straightforward and relatively simple erection procedures. The precision with which the Micro-Lam billets, web members, and fasteners were prepared at the Trus Joist plants resulted in nearly perfect matings at joints and splices. The second factor was the ingenuity used by the MacGregor Triangle and Grays Crane and Rigging companies in detailed planning and carrying out of the erection work. Assemblying the roof arches involved careful timing so that the thousands of parts for the trusses could be properly assembled into the individual arch segments in time to conform with the final erection schedule. New and innovative equipment was designed for use in the erection work. A special technique devised to erect the massive half arches consisted of three large steel lifting trusses designed to spread the lifting or erection loads over each half arch as it was lifted into place. Grays Crane and Rigging Company developed a special C-clamp that lifted from the steel portion of the trusses and could be removed from one side.

Impact on the physical environment, unusual aspects, and esthetic values

The new ASUI Activity Center is an attractive addition to the many modern-looking buildings on the University of Idaho campus. It also fits well into the surrounding environment. The Palouse hills of northern Idaho and eastern Washington within which the City of Moscow and University of Idaho are situated have characteristically smooth and rounded shapes. The smooth arched roof of the stadium blends well into this setting. The exposed concrete surfaces tend to be neutral in appearance and several coats of all-weather paint, of various colors, were sprayed on the end walls to compliment the surrounding structures and the nearby countryside.

The completion of the covered stadium at the University of Idaho, the first of its kind in the world, will usher in a new era in the athletic program at the University by providing a badly needed all-weather field for a wide variety of college sports, while at the same time an excellent facility is provided to the people of the region for an almost unlimited variety of non-athletic events.

Manuscript prepared by John J. Peebles, F. ASCE

University of Idaho roof system first of its kind in world

MOSCOW, Idaho – The University of Idaho Stadium will be the first of its kind in the world to use a lightweight composite wood and steel system to span 400 feet with a center height of slightly more than 140 feet or the equivalent of a 14-story building.

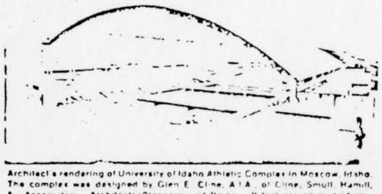
The unique wood and steel structural system was designed by Arthur L. Troutner of Boise, a University of Idaho alumnus and the co-founder of TRUS JOIST Corporation.

Emerick Construction Co., of Portland, Ore., is the general contractor for the $4,164,000 phase of the structure designed by Glen E. Cline, A.I.A., of Cline, Smull, Hamill, & Associates, Architects/Planners, of Boise. MacGregor Triangle Co., of Boise, was subcontracted for the erection of the roof, with Gray Crane Service of Seattle, Wash., furnishing the equipment.

H. Robert Coulter, chief estimator for Emerick Construction ... his first thought when h... at the tremendous ... the project ... Cline ...

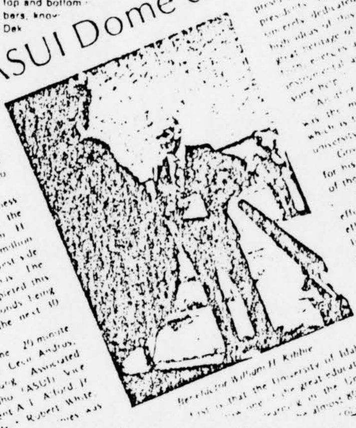
... ted by TRUS JOIST met all the requirements established by his firm. This system is a composite of trussed arches using ... steel web members and ... top and bottom ... bers, know... Dek...

... pounds ... feet ...



Architect's rendering of University of Idaho Athletic Complex in Moscow, Idaho. The complex was designed by Glen E. Cline, A.I.A., of Cline, Smull, Hamill, & Associates, Architects/Planners, of Boise. It features an arched roof spanning 400 feet and is the first in the world to utilize a new lightweight composite wood and steel system.

Kibbie-ASUI Dome dedicated



Benefactor William H. Kibbie

The man whose $300,000 gift made it possible for the University of Idaho to start putting a roof on its football stadium said Oct. ... it was the prominence of the university and the stature of its president that led him to make the donation.

William H. Kibbie, Salt Lake City business executive, made the remarks during the dedication ceremony for the William H. Kibbie ASUI Activity Center, a $7.8 million multi-purpose facility located on the west side of the University of Idaho campus. The structure, started in 1969 and completed this fall, is financed largely through bonds being paid through student fees over the next 30 years.

Other speakers during the 20-minute ceremony included Idaho Gov. Cecil Andrus, UI President Ernest Hartung, Associated Students University of Idaho (ASUI) Vice President Max Beatty, Regent A. L. Alford Jr. and Vandal Booster President ... of Lewiston, Master ... ASUI President David Warnick ...

... Kibbie told a near almost 17,000 people ... interested to know ... in the university and ... people have ...

... presided over by one of the finest university presidents in the United States. A man sincerely dedicated to the maintenance of the high ideas of this school and to continuing its great heritage of the past. I must say that the ... and goals of Ernie Hartung were instrumental as well in my decision to render some help.

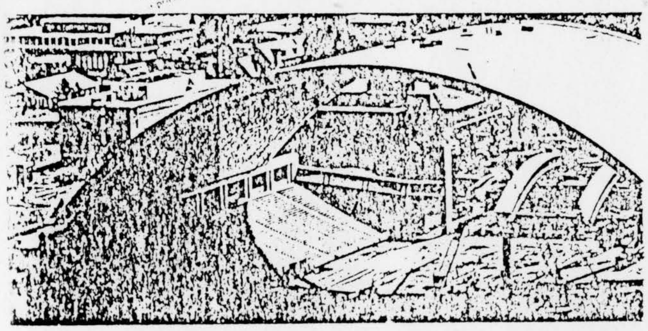
Another factor which appealed to Kibbie was the multi-purpose nature of the facility which is to be used by the students of the university, not just by intercollegiate athletics.

Gov. Andrus expressed thanks to Kibbie for his "singular gift" but also to the students of the university.

"Mr. Kibbie's effort is certainly a singular effort and a great one, but there is a collective effort by the students of the University of Idaho that are here now and in many years to come that have made ... people of the state ... pleased that ... did this but we ... facility that will ..." Andrus said.

... said ... big step for ... institution ... meeting the ... students ...

creative engineering in structural wood

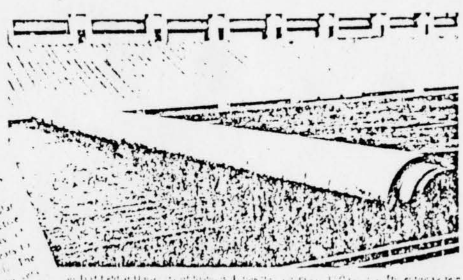


TARTAN Facts

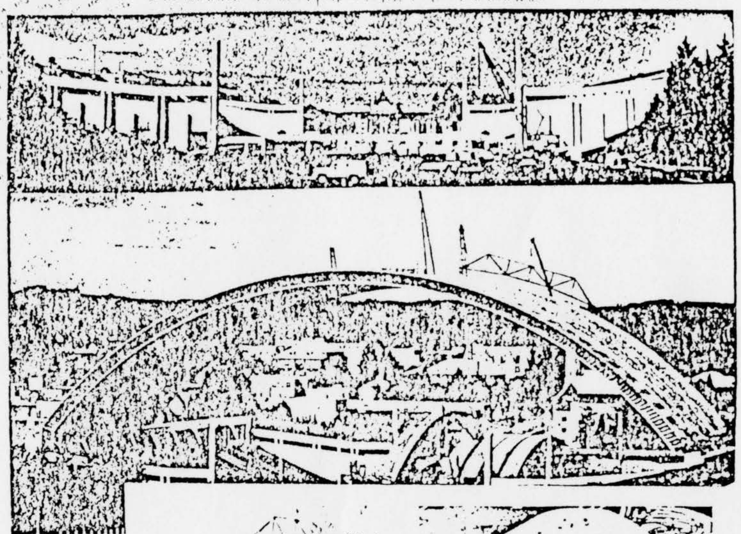
3M COMPANY

Idaho Has 1st One-Piece 'Portable' Gridiron

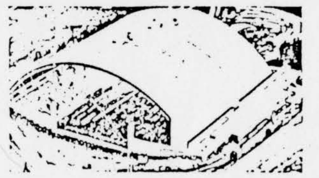
74,000 Square Feet of Tartan Turf Removed, Replaced Mechanically; Element In Plan For World's Most Imaginative Multi-Purpose Stadium



Multi-Purpose Use



Half arch piece ...



Cover ...

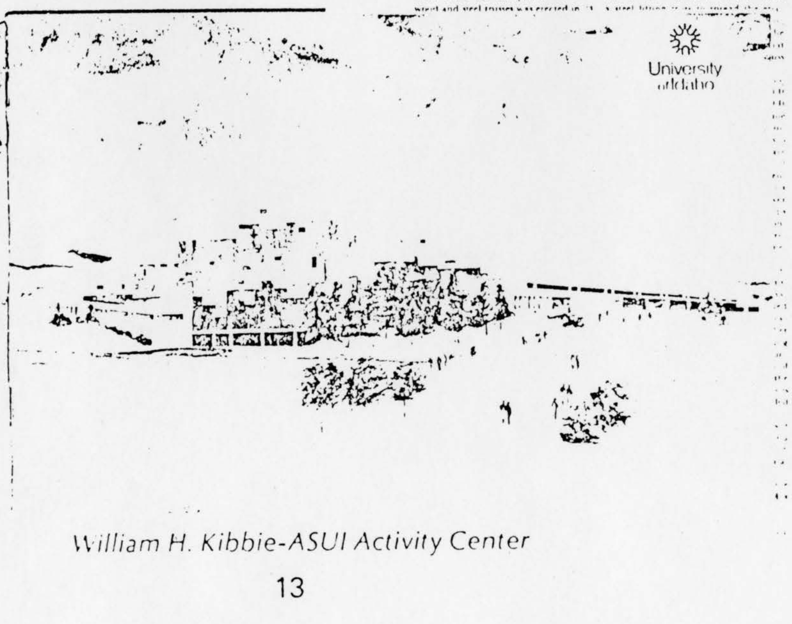
Four-acre arch truss roof erected in 24 days

... and horizontal deflection caused by both wind loads and arch ...

The end walls are ...

Heated debate. ...

William H. Kibbie



University of Idaho

DEDICATION PROGRAM

Presiding	M... David Warnick *President, Associated Students University of Idaho*
Remarks	Dr. Ernest W. Hartung *President, University of Idaho*
	Hon. Cecil B. Andrus *Governor, State of Idaho*
	Mr. William H. Kibbie *President ...*
Regent's Acceptance	... *Vice President, Board of Regents*
Presentation	M... ... *President, Vandal Boosters*
Student Response	... *Chairman ...*

William H. Kibbie-ASUI Activity Center