# BUILDING TOMORROW'S SCHOOL TODAY

### Education & Infrastructure

Public schools are facing an infrastructure crisis as industry and government reports lament the current state of disrepair of school buildings in the face of rising student enrollments and increased demands for technology in the classroom. K-12 enrollment hit record levels last year, and a growth of 18% is forecast over the next decade, with an even more dramatic 33% increase projected at the high school level. The federal government's General Accounting Office reports the nation's public schools are in need of $112 billion for major repairs and expansion,

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## Combined library/classroom space is designed to accommodate future technology

**By William Andrews, S.E.**

Faced with a growing student body and the need to increase access to new technology, the Davis (CA) Joint Unified School District recently embarked on an ambitious master plan for renovation and expansion. Developed by The Steinberg Group of San Jose, CA, the facilities master plan is designed to carry the 30-year-old high school into the next century.

The centerpiece of the plan is a new steel-framed, $4.1 million Library/Classroom building, with structural engineering provided by DASSE Design, Inc., of San Francisco.

The architect's programming goal was to fulfill the District's philosophy of education, which is to develop in students the knowledge, skills, character, and values of discipline, responsibility, honesty, fairness, and a desire for lifelong learning, in a safe and nurturing environment. The new building creates the main entry into the campus of 1,400 students and responds to the urban elements of the surrounding neighborhood as well as to the quad area. The 33,000-sq.-ft., two-story facility combines 15,000 sq. ft. of library space and 18,000 sq. ft. of classroom space. The library is a media center, with 6,000 sq. ft. for book stacks, electronic card catalog and CD-ROM research stations, plus instructional areas, a computer lab and an audio/visual center.

The library stack area is a 40'-tall, open space with exposed structural steel braced frames and suspended air conditioning ducts. Abundant natural light is provided through a full-height glass and metal curtain wall on the north face and curved ribbons of glazing on other walls. The natural light is supplemented with artificial lighting reflected off a curved ceiling.

Solar aspects are incorporated into the design to respond to the functionality of the building, the locale's climate, and to the environmentally conscious community. Sun control elements are strategically placed along the building's

*Pictured at left is the Davis High School library's main entrance with its 40'-high glass wall. Shown below is the library stack/reading space with exposed structural and mechanical elements.*

south wall to limit heat gain from the afternoon sun and reduce building cooling loads, saving the district money on its utility bills in the spring and fall. The desire to accommodate future changes in classroom technology and teaching methods placed a high priority on creating short and long term space flexibility. Classroom walls are non-load bearing partitions comprised of metal studs and gypsum wall board, which can be easily reconfigured to accommodate future space plans and incorporate electrical and mechanical alternations required by new technologies.

## Framing System

The building is a Type II N (sprinklered) steel-framed structure designed in accordance with the 1991 Uniform Building Code (UBC), as amended by the Division of the State (CA) Architect for school construction. The building contains 234 tons of A36 wide flange steel and A500 Grade B tube steel, and 31 tons of prefabricated steel open web joists supplied by AISC-member Vulcraft. Columns are typically W8 members, with bays varying from 26' to 33'.

The main roof construction is a single-ply membrane roofing over rigid insulation and 1½"x18 gage metal deck supported by steel open web joists and wide flange girders. The second floor construction is 3½" of regular weight concrete fill over 1½"x18 gage composite metal deck supported by steel open web joists and wide flange girders. Girder shapes were limited to W18s to permit passage of mechanical ducts in the limited ceiling space underneath. Girders were designed as unshored, composite beams, cambered for deflections due to the weight of the framing and concrete fill. The ground floor is a reinforced concrete slab on grade.

The lateral force resisting system is a steel concentric braced frame, with frame design lateral forces governed by the earthquake provisions for UBC seismic zone 3. The foundation is a system of conventional spread footings and grade beams. The exterior wall system is a combination of cement plaster over light gage steel studs and storefront glazing.

The architectural focal point of the library space is the curved roof and ceiling. The roof framing consists of W16 beams curved to a radius of 132', covered

### Education & Infrastructure, Cont.

yet state and federal governments spent just 3% of what was needed in 1994. While rapidly becoming a reality in some school districts, portable classrooms and double sessions are not—and should not—be considered realistic long-term answers to persistent growth.

In the face of these soaring enrollments and antiquated facilities, beleaguered school districts also are struggling to bring modern technology into the classroom. In California public schools, where the long-term goal is to have one computer for every four students, currently just one computer is provided for every 73 students.

Based on a survey of recent academic studies linking improved student performance in language arts, math, science and social studies to technology-based instruction, experts conclude that inclusion of technology in the classroom is considered even more important than reducing class size, raising teacher salaries or increasing hours of instruction. School designers are being prodded by the educational community to restructure traditional classrooms, science labs and support areas to address burgeoning student enrollments and changes in teaching methods, curriculum and technology.

## DASSE's Quality Assurance Checklist

### Coordination
- Dimensions shown on structural match architectural
- Call-outs are correctly cross-referenced
- A path exists to all details
- State typical and minimum clearance for mechanical systems between ceilings and bottom of structure
- Roof elevations are adequately defined by architect or structural, or both
- Roof elevations provide sufficient slope for the entire roof ($^1/_4$"/ft. min.)
- Horizontial dimensional control clearly stated
- Vertical dimension control clearly stated (top of slab, top of steel, etc.)
- Partitions and ceiling bracing adequately detailed by architect
- Mechanical equipment support details provided
- Cladding issues adequately addressed on drawing (who is responsible for detailing; acceptable loadings and loading locations defined)
- What is fire rating classification of building? What is required fire separation between floor? How achieved?
- Framing at all levels, including roof provided to brace elevator rails at maximum of 15' o.c. (8' for OSHPD)

### Welded Connections
- All welds prequalified with AISC
- Field welds only where required
- Complete penetration vs. partial penetration welds clearly and efficiently specified

### Bolted Connections
- If mixing bolt types (i.e. A307 or A325), different sizes used
- Single plate shear tab connections consider rotation
- Block shear conditions checked
- Prying action considered where appropriate
- Combined stresses considered where appropriate

### Columns
- Transverse loads from cladding connections included in calculations?
- Eccentricity of loads considered at perimeter and other non-concentrically loaded columns
- Column splices shown at 3' to 4' above floor level
- Live load reduction properly utilized (Live load reduction from roof area should not be applied to next lower level if it yields a lower live load than would otherwise be the case)

### Steel Deck
- Deck depth, gauge, fastening and span adequate for both vertical and lateral loads, including any single span conditions? Shoring called out if required
- Deck designations consistent between plans and schedule
- Vented deck provided at locations with concrete fill covered by a water-proof membrane? (i.e. roofs and decks)
- Deck support at "wet" columns covered?
- Are deck cantilever conditions detailed and supporting calculations (including cladding loads) provided?
- Is a construction joint detail in concrete fill over deck included?
- Typical opening details provided? Larger openings framed in plan? Diagonal trim rebar shown at larger openings?

### Steel Joists
- Panel points specified to be aligned so that services can pass easily through joists?
- All special loadings, such as mechanical penhouse or screeens, point load requirements, collector loads, etc., are included?
- Depth of bearing at ends of joists coordinated with manufacturer requirements? (6" required for heavy loaded joists and girders)
- Detail provided for deck support and shear transfer at girders

### Framing
- Framing notes completely define "marks" used
- Elevation of framing defined at all levels

### Steel Beams
- Stud spacing on beams coordinated with flute layout 70% - 80% composite
- Beams cambered for calculated dead load deflection
- Typical beam connection table checked for project loads
- Typical beam vibration characteristics checked
- Special loading conditions incorporated into design
  - public assembly
  - roof mechanical units
  - other (list) drag loads
- 50 ksi steel, if used, is clearly specified
- Spandrel beams braced for interior cladding support
- Short horizontal slotted holes provided in beams framing into concrete walls
- Moment connections detailed at cantilever conditions

### All Braced Frames
- Describe lateral load path from baseplate to soil
- Are drag connections completely detailed?
- Do shear lugs clear grade beam reinforcement
- Oversized holes in baseplate acceptable?
- High strength anchor bolts checked availability?
- Foundation system strength sufficient to ensure yielding occurs in braced frame
- Is relationship between centerline and column connector plate centerline clearly defined? (particularly at braced frame gusset plates)
- Tube sections b/t less than or equal to 110 over the square root of $F_y$
- Compression elements b/t compactness requirements (AISC Table B5.1). Tube steel members should have b/t less than 15
- Bracing checked for $l/r$ per 2710(h)2. For angles use $r_2$
- Bracing connections designed for strength per
  i. tensile strength of brace or
  ii. 3($R_W$/8) seismic force or
  iii. maximum force transmitted
- Chevron bracing designed for 1.5 times other prescribed forces

with 3" metal deck running perpendicular to the curve. The additional cost of curving the wide flange beams worked out to just $0.64 per sq. ft.

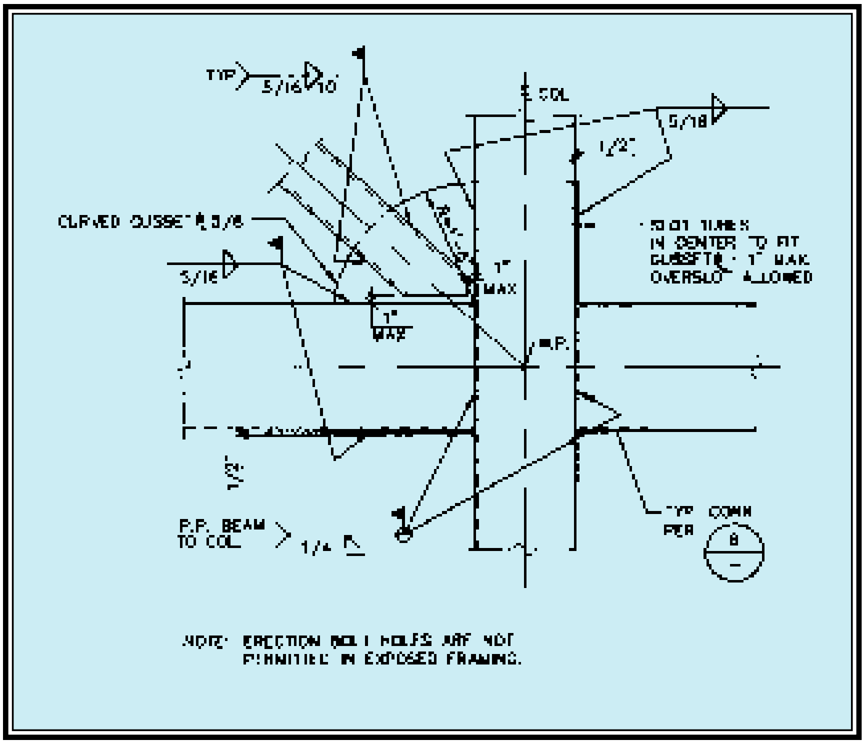
The library space is surrounded by exposed steel tube frames (TS14x14 columns, TS16x12 and TS18x12 beams and TS8x8 braces). Exposed connections are all-welded, with architecturally curved gusset plates and tight erection tolerances on the braces. The library curtain wall system is laterally supported by the exterior tube steel columns, which span up to 40' vertically to resist out-of-plane wind pressures corresponding to 75 mph and exposure C.

A vibration study of the second floor open web joists was performed early in the design stage to determine the most efficient deck, fill and framing system. Initial studies found thin 2½" concrete fill over deck with joists spanning 31' yielded a system with "distinctly perceptible" vibration characteristics (as defined by Lenzen's Modified Reiher-Meister Plot of Human Response Domains for Transient Vibration of Steel Joist-Concrete Slab Floors), which was undesirable for a classroom setting. However, by increasing the fill to 3½" thick, the vibration frequency was reduced to 7.3 hertz, which plotted in the "slightly perceptible" range and was deemed acceptable.

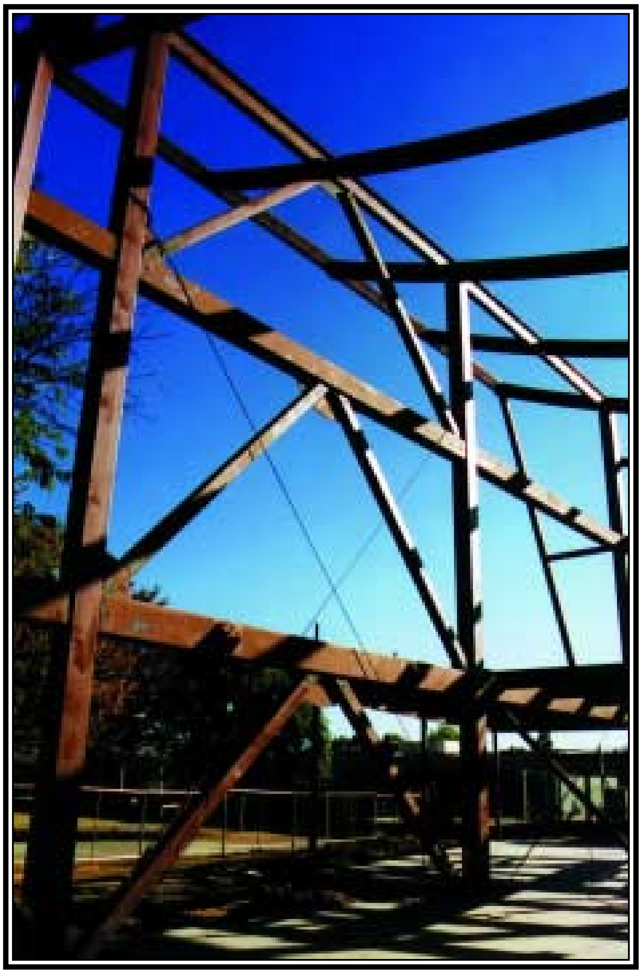
Unique architectural features that were framed with structural steel included a curved stair and sun control shades.

The stair is an 8'-wide helix, curved in plan with an inside radius of 19'. The stringers were originally designed as TS18x6x⅜, but were eventually fabricated from two MC18s. The flanges were trimmed to 3" wide and joined together with a complete penetration groove weld to achieve an overall 18" by 6" profile. The stringers, perforated plate treads and railings were fabricated together in the shop, and the entire stair was shipped and erected as a single assembly.

The sun shades are light gage




*Shown at right is the chevron bracing during construction. The bracing consists of 8"x8" hollow structural sections, while the columns are 14"x14" HSS.*



steel studs and welded angle assemblies cantilevered and suspended from the roof and second floor framing along the south wall. Tapered shapes and changing slopes required careful coordination not only between architect and structural engineer during design, but also continued with the steel detailer, fabricator and general contractor to achieve a successful installation.

## Cost Control

As with much school construction in California, this project was originally conceived as a wood-framed structure with a minimal amount of structural steel. However, at the completion of the schematic design phase in the spring of 1993, lumber prices were steadily increasing and unstable, while steel prices were flat or dropping. A value engineering session with the design team and the project construction manager, Vanir/3DI, Sacramento, revealed that a steel-framed solution was less costly and more reliable from a construction budget point of view. This was very important to the school district, whose funding source was a recently approved local bond measure and real estate developer fees.

Cost estimates were then performed by the construction manager at three successive milestones prior to the bid to confirm design costs were not straying beyond the budget. Design team members reviewed the estimates relative to their disciplines and reported omissions and overages to the construction manager. This method proved highly successful and the winning bid was $200,000 below budget, allowing the district to set aside a portion of the remaining budgeted money for desperately needed furnishings.

## Quality Assurance

DASSE Design, Inc., employs an internal quality assurance program in an effort to produce structural drawings that are technically consistent, coordinated with other disciplines, constructable and in compliance with applicable design criteria and building codes. This process includes involvement by a firm principal throughout the project, a detached review by a senior structural engineer not involved in the design and completion by the project engineer of a QA checklist for steel buildings—a checklist that includes more than 75 items.

For this project, design team meetings were held roughly twice a month during the height of the construction document phase to resolve coordination issues in this complicated building. Many of the architectural features that give this building its unique character are complex, unconventional geometric shapes that required detailed structural support. Structural coordination with electrical requirements included location of underslab electrical ducts and provisions to thread electrical service through the center of the library tube steel columns and beams for face mounted light fixtures.

Tight ceiling spaces restricted the sizes and locations of air conditioning ducts passing through the open web joists and under flange girders. Sizes and locations of roof mounted HVAC units were pre-selected to define corresponding equipment loadings to the steel joists.

Before a building permit can be issued for a school, the Office of Regulation Services (Division of the State Architect) reviews all construction documents for structural compliance with the governing code. One unique requirement of ORS is that prefabricated structural members, such as open web joists, must be included in the structural drawings fully designed and completely detailed. This brought Vulcraft into the process much earlier than would normally occur on a non-school project. Though it required more work up front by DASSE and Vulcraft in the design phase, it ultimately resulted in a shorter lead time for fabrication and delivery of the joists and in fewer field problems.

The intense coordination efforts by the design team and implementation of other quality assurance measures resulted in a project that was completed under budget and within the 13 month construction schedule.

*William Andrews, S.E., is project engineer with DASSE Design Inc., a consulting structural engineering firm headquartered in San Francisco with an additional office in Irvine, CA and celebrating its 10th anniversary this year.*

*Pictured at top is the library's south wall, showing the sawtooth second floor and cantilevered sun shades. The architectural focal point of the library space is the curved roof and ceiling, as shown in the construction photo above. The roof framing consists of W16 beams curved to a radius of 132', covered with 3" metal deck running perpendicular to the curve. The additional cost of curving the wide flange beams worked out to just $0.64 per sq. ft.*