Innovative Accessible Sunken Floor Systems for Multi-Story Steel Buildings

by

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ABSTRACT

With the demands of telecommunications and computer equipment, building owners and designers are facing an increasingly difficult problem for wire management in today's electronic workplace. This thesis is to investigate and design the accessible *sunken floor systems* for multi-story steel buildings with proliferating data cables and mechanical equipment.

The terminology of an accessible *sunken floor system* or a *dropped floor system* is not new. *Sunken floor* has been used in reinforced concrete buildings with flat slabs and multi-story steel-framed construction with solid wide-flange beams. However, the design of an accessible *sunken floor system* with open-web steel joists and joist girders is an innovation, by leading steel design and construction industry into a new era.

Sunken floors are similiar to raised floors, which are composed of removable square floor panels on metal pedestals to provide space for electrical or mechanical equipment or both. The removable panels provide easy access to the equipment below. These floors are commonly used in computer rooms, clean rooms and new office buildings which require extensive mechanical and electrical service. A clean room environment with air return through accessible plenums is essential in microelectronics and pharmaceutical facilities, in hospital operating rooms, in bio-genetic research laboratories and production areas, and in assembly plants for items such as computer disk drives and compact disks.

Accessible *sunken floor systems* are used to avoid ramps or stairs as opposite to raised floor systems. Also, the finished floor-to-floor height in multi-storey construction is less than the acceptable height for a raised floor, with subsequent savings on other more expensive building materials. Moreover, the construction cycle for steel buildings with open-web steel joists and joist girders is faster if the finished floor is composed of removable floor panels. One of the proposed systems is to substitute conventional concrete metal decks for fire-rated acoustical ceilings and horizontal bracings to cut down the construction cycle and costs. A second variation of the proposed systems permits economies in concrete slab finish by using lightweight concrete poured on corrugated metal decks, or by using pour-in-place or precast slabs below the finished floor panels, and the floor system is suspended 4 inches below the top chord of the steel joists as a horizontal diaphragm and fire barrier.

This thesis will explore the building system integration and forecast the construction cycle and costs. An evaluation of the proposed systems will be presented with matrix diagrams to summarize the conclusion of this paper.

Thesis Supervisor: ***Timothy E. Johnson***
Title: Principal Research Associate

Chapter 1 *Introduction*

"The design of the proposed floor systems is based on the technologies from accessible raised floor used mostly in computer rooms, and also interstitial floor used mostly in hospitials."

Access floors have been widely used in open-plan offices, hospitals, laboratories, assembly plants, schools, computer rooms, television studios and telephone-communication centers etc.. Accessible raised floors provide accessibility to mechanical and electrical services with flexibility in the placement of desks, machines, computer modems, telephone services, manufacturing and general office equipment. Access floors have also been used in a recessed area of a structural floor with solid wide-flange beams or concrete flat slabs for future changes; however, *sunken floors* with solid wide-flange beams are poor for electrical and mechanical supplies without web openings.

Accessible raised floors have a high initial cost, but a more affordable life-cycle-cost analysis can be used with a minimum cost in changing the wiring layout. Raised floors reduce floor-to-ceiling height with less head room for the building occupants or higher floor-to-floor dimensions with conventional ceiling height. Certain city codes prescribe a maximum height to which buildings can be constructed. Higher floor-to-floor dimensions reduce the gross floor area for multi-story buildings in downtown locations with the highest rental rates, together with the consequent disadvantages of higher cost for walls, plumbing, wiring, ducts, elevators and foundations. A low ceiling height is limited in its efficiency in air-conditioning and natural daylighting. Interior partitions for individual work stations produce a large stagnant zone between the floor and some distance above it. Public Works Canada performed a study on an open-plan office building served by supply-air and return-air vents located in the ceiling. It was demonstrated that little supply air reached workers seated at their desks. The result was a form of short-circuiting; some supply air was drawn directly into return air vents where partitions approximately five feet high divided the area into workplaces.

Steel skeleton structures are easily removable and be reintroduced into the raw-material cycle. In multi-story steel framing, structural columns consume minimal space and permit maximum net floor area. Structural steel must be protected with fireproofing.

However, the additional fireproofing cost is often offset by savings in the construction time, the superstructure cost, the increased net floor area provided by steel framing and a fast repayment period for clients with an affordable interest rate. With a faster construction cycle in 1986, some clients can save as much as $55,000 per day for a project or more than a million dollars in three weeks without a project delay. Steel framing is still faster to erect than reinforced concrete framing, especially in fast-track construction with high interest rates on debt service during the design and construction. There are many advantages about fast track construction, especially for certain types of buildings such as commerical office buildings, for a client in a volatile market who needs to produce a product quickly, or for a contractor who needs to pour the foundation before the severe winter weather.

The design of the proposed floor systems is based on the technologies from accessible raised floor used mostly in computer rooms, and also interstitial floor used mostly in hospitials. This thesis is to demonstrate the advantages of open-web steel joists or modified steel joists with a *sunken floor system*, for accessibility to and flexibility of mechanical and electrical functions. The actual cost saving has to be determined by the scale, type and location of the project with or without fast-track construction. Generally, with optimum joist spanning and maximum area per floor, cost saving will be increased by adding more gross area for multi-storey buildings under a height limit, or by reducing the overall building materials and construction costs. The floor to ceiling height is maintained at a recommended height of 9'-0" for efficient air conditioning and natural daylighting, but the plenum space of a *sunken floor* is less than that of a raised floor with optimized joist spanning, and fewer expensive building materials such as exterior cladding, marble or granite will be used. The new construction techniques will be evaluated throughout the thesis, and it concludes that accessible *sunken floor systems* can be practical under certain safety precautions.

Chapter 2 *Studies on the Accessible Raised Floor Systems with Current Technologies*

"Nevertheless, because of the increasing demand for flexibility and the growing complexity of services, their use is on the rise."

Raised floors provide accessibility to mechanical and electrical supplies and flexibility for the placement of desks, telephone services, machines, computers, and equipment etc.. The growing use of raised floors in offices is influenced by the open office plan, the practice of rearranging workstations and having more workstations outfitted with terminals.

There are several types of accessible raised floors, mostly recognizable by their substructures and squared floor panels. The substructure consists of steel or aluminium pedestals which are bolted onto the structural floor, or adhered to the floor with adhesive, and designed with threaded shafts to allow for height adjustment. The pedestals with either bolt or snap-on connections, support the floor panels at their corners or along their edges using stringers. Shallow floors are comprised of large panels laid over timber battens, or a metal decking fixed to the sub-floor with a less than 4" deep cavity. Timber battens have to be treated with fire retardant to render them incombustible.

Floor panels are constructed of reinforced steel, aluminium, hollow metal, insulated metal, metal pan with lightweight concrete fill, or metal with wood fill and laminated panel with aluminium honeycomb core. The aluminium costs more than other materials, it offers light weight, high strength, no magnetic interference, and no possibility of rusting, making it more common in high-performance applications such as clean rooms or to hold computers because metallic dust is eliminated. The chipcore panels are inexpensive, but highly combustible and extremely reverberant in comparison with other panels. The cementitious panels have considerable rigidity and have a more solid feel and sound. They add about 10 pound per square foot to live load. The only drawback is their weight. Steel panels are available in three structural grade: heavy duty, computer and general construction.

Panels are available with finished surfaces of vinyl, vinyl asbestos tile, plastic laminate, resilent carpet, wood and reinforced stone. Carpet could be permanently adhered to the panels or temporarily adhered with release-type adhesive under the carpet tiles to facilitate their removal. Some manufacturers align the panel and carpet joints for easy access to the floor plenum. Others recommend overlapping the carpet and panels to obscure the panel joints. Wraparound, butt, and protective plastic edge carpet systems are available. Carpet tiles are inexpensive and solve esthetic problems that occur when workstations change to meet changing needs. Tiles from high- and low-traffic areas can be switched to extend the life and good looks of carpet in the ever-changing environment.

Panel sizes are 18x18 in., 24x24 in., 30x30 in. and 48x48 in.. Panel systems generally rely on gravity held connections, but can be mechanically fastened, increasing rigidity but reducing speed of removal. Panels with bolted stringers are easier to lift, but the stringers decrease the accessibility of cables. Snap-on panels and stringers offer less rigidity, but easier installation and faster panel relocation. Some panels are available with rubber gaskets to decrese panel reverberation. Removable stringers provide less hindrance because of the ease with which they can be removed. Some panels are designed with plastic wipers along the edges for mechanical services; in addition, these also help to achieve the tolerances required acoustically. A class A flame spread rating is available in some panels. Relocating the outlets can be as easy as lifting, moving and reconnecting activated panels.

An access floor has almost unlimited cable capacity and routing. Power may be enclosed in hard-wire or flexible conduits, but electronics and communication can be installed without raceways when the floor is not used as an open plenum for HVAC. The new aluminium-sheathed Ready/Clad as type MC cables can be used in plenums. The metal jacket of an MC cable serves as its equipment-grounding conductor. Faster installation is achieved by removing the thin aluminium sheathing with a knife instead of a hacksaw and pipe cutter. While cable capacity continues to increase, cable size is decreasing, making a 6- or 4-inch underfloor cavity adequate for the distribution of cables.

Space beneath floors can be utilized as underfloor plenum for HVAC or as an unpressurized supply- or return-air plenum, offering empolyees the possibility of individual climate control by using special panels with perforations for air distribution. Cable slots, sound, and thermal insulation are also available. Thermally insulated panels can reduce the possibility of condensation when under-floor space is used for air-conditioning. A height of 7 to 18 inches is common where the underfloor area is used for ductwork as well as electrical distribution. A floor raised over 1 foot above the subfloor may provide a hiding place and thus pose a potential security problem. Electrical outlets can be flush, concealed, or surface-mounted.

The floor surface must be conductive and grounded to avoid accumulation of static electricity and to prevent electrical shock. Static control can usually be accomplished by maintaining a high relative humidity in the area and by using resistive finish materials. Some floors are required to be nonmagnetic. An automatic fire detection system should be installed in plenums below floors. Plenums may not exceed 10,000 sq. ft. in area and must be divided by noncombustible bulkheads. If the floor is used as a plenum or to house ductwork, special dampers may be required to seal off the space in case of fire. The access floor cannot be used as a foundation for fixed, full-height partitions. Partitions that subdivide computer spaces should be integrated with the fire-resistance requirement. If inert gas is used for fire suppression, the partition must be provided with an airtight seal.

Raised floors provide good acoustical isolation. Mechanical fasteners, concrete infill and insulation can relieve the noise generated from moving or rolling loads. Raised floors are surrounded by partition systems within the building interior. Windowsill heights and the location of perimeter mechanical units must be considered when floor panels abut an exterior wall.

An accessible raised floor system is expensive to install: it is about 80 cents a square foot more than underfloor duct with ceiling and ceiling/furniture lighting, but it is 42 cents a square foot less expensive than underfloor duct with furniture lighting.[1] An access floor makes wiring changes so easy that they can be done by janitors or secretaries with minimum cost and more affordable life-cycle-cost analysis.

A raised floor system is also less resistant to heavy rolling loads. Poor placement of exceedingly heavy loads can damage floor systems. Wet washing techniques may not be used; however, a resilent finish similar to an adjacent sheet vinyl floor may allow janitors to wet-wash the access floor. Accessible raised floors reduce floor-to-floor height with less head room for the building occupants, or a higher floor to floor dimension is required with more spending on the building materials. The ideal floor-to-ceiling height may be 9 feet , but 8 feet 6 inches would be acceptable with layout flexibility. Today's access floors do not provide for ceiling lighting; supplementary hard-wire or flexible conduit is required in the ceiling plenum. The dimension of the panels must be precise and this requires systematic space planning. Stairs and ramps must be constructed in the absence of a dropped floor slab to provide entrance to a raised floor area. Bathrooms and washrooms must use conventional floors, which creates another problem in accessibility.

Raised floors are not the only answer for telecommunications; moreover, many other wiring systems serve the same purpose at a lower cost. Nevertheless, because of the increasing demand for flexibility and the growing complexity of services, their use is on the rise.

The following chapter 3 & chapter 4 are the essence of the entire thesis. These chapters illustrate the new construction technologies, which are combined with existing or new steel framing technique. The concept of a *Sunken Floor System* is based on the existing raised and interstitial floors.

Chapter 3 is the design strategy of the *Economical Model,* which is based on the existing steel framing technique of floor construction. As in the conventional construction, bar joists or open-web I-beams are used as the structural supports for floor loads. However, there is no permanent floor slab within the proposed systems. The permanent floor slabs are replaced by the accessible floor tiles bolted on pre-installed floor anchors, or tiles directly bolted on the upper chords of the floor joists or beams. The accessible floor tiles are modified from the existing products for the raised floor systems. They should be fire-protective and fire-rated. A lightweight concrete tile reinforced with steel wire-mesh is recommended for the proposed floor systems. The tiles should be desiged with fire-rated gaskets around their edge to prevent smoke, water, as well as fire penetration. A fire-rated ceiling is suspended from the steel joists or beams to protect the structural members from the fire below. With the absence of a permanent floor slab, wind bracings or space-frame-like structures are used to resist horizontal wind or seismic loads.

Chapter 4 is the design strategy of the *Supreme Model*, which is designed with the modified steel joists or beams. A *Composite Web Joist or Beam* is a truss welded on another truss. The upper truss is manufactured with shear metal plates, and the lower truss is similar to any existing truss. A permanent slab is designed to be supported by the lower chord of the upper truss, which is also one of the significant differences between the *Economical Model* and the *Supreme Model.* To reduce the unusable spaces within the plenums, the accessible floor tiles are directly laid on the top chords of the upper trusses. They are also laid on the pedestals sunkened below the top of the floor joists or beams. The accessible floor tiles can be directly available from the existing products which are designed for the raised floor systems. An acoustic ceiling is suspended from the floor joists or beams for the floor below.

Chapter 3 *An Outline of the New Construction Technique and Design Strategy (Part 1)*

"The Economical Model has the capability to compete with the conventional construction."

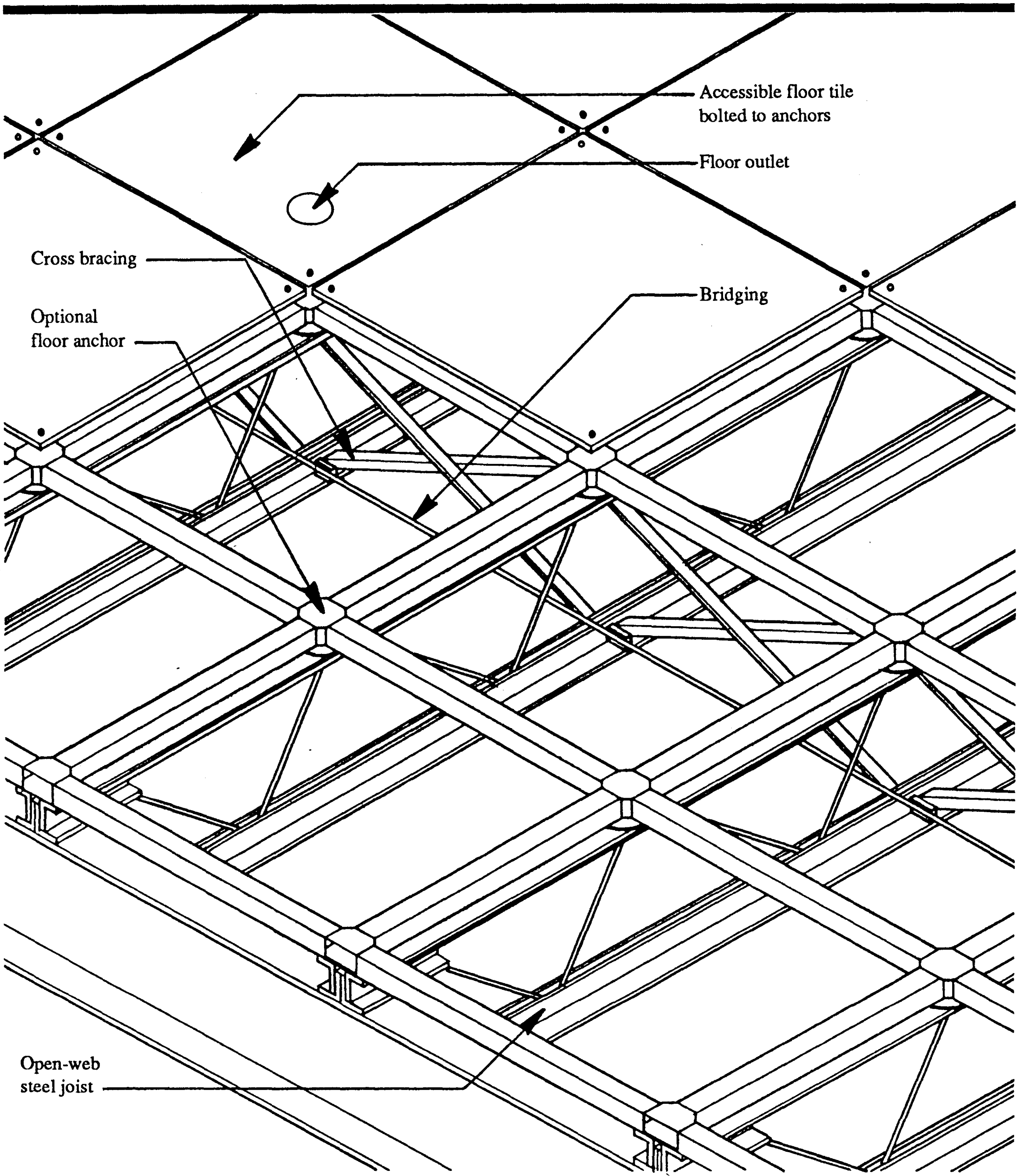


Figure 1:- Economical Model (alternative 1).

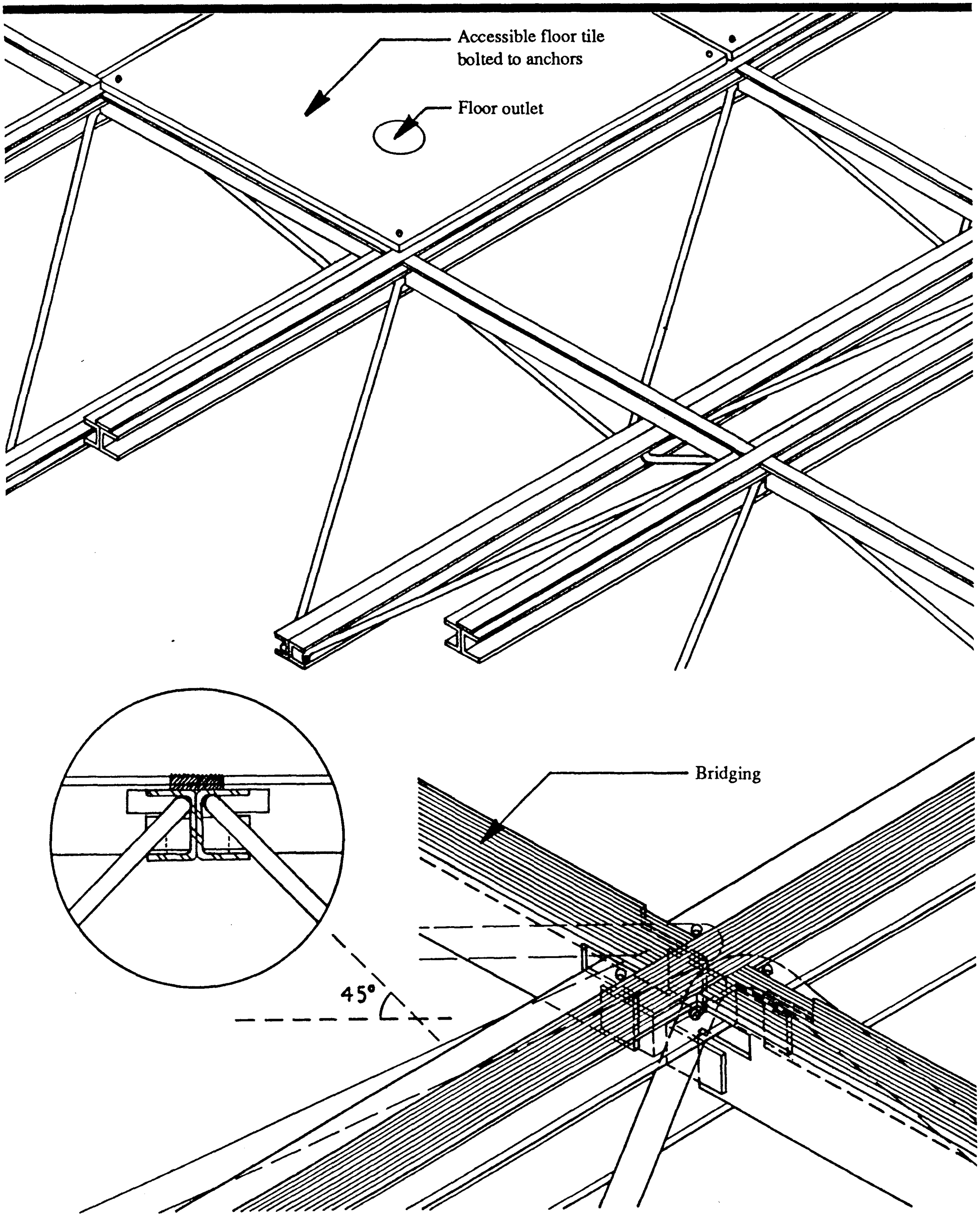


Figure 2:- Economical Model (alternative 2).

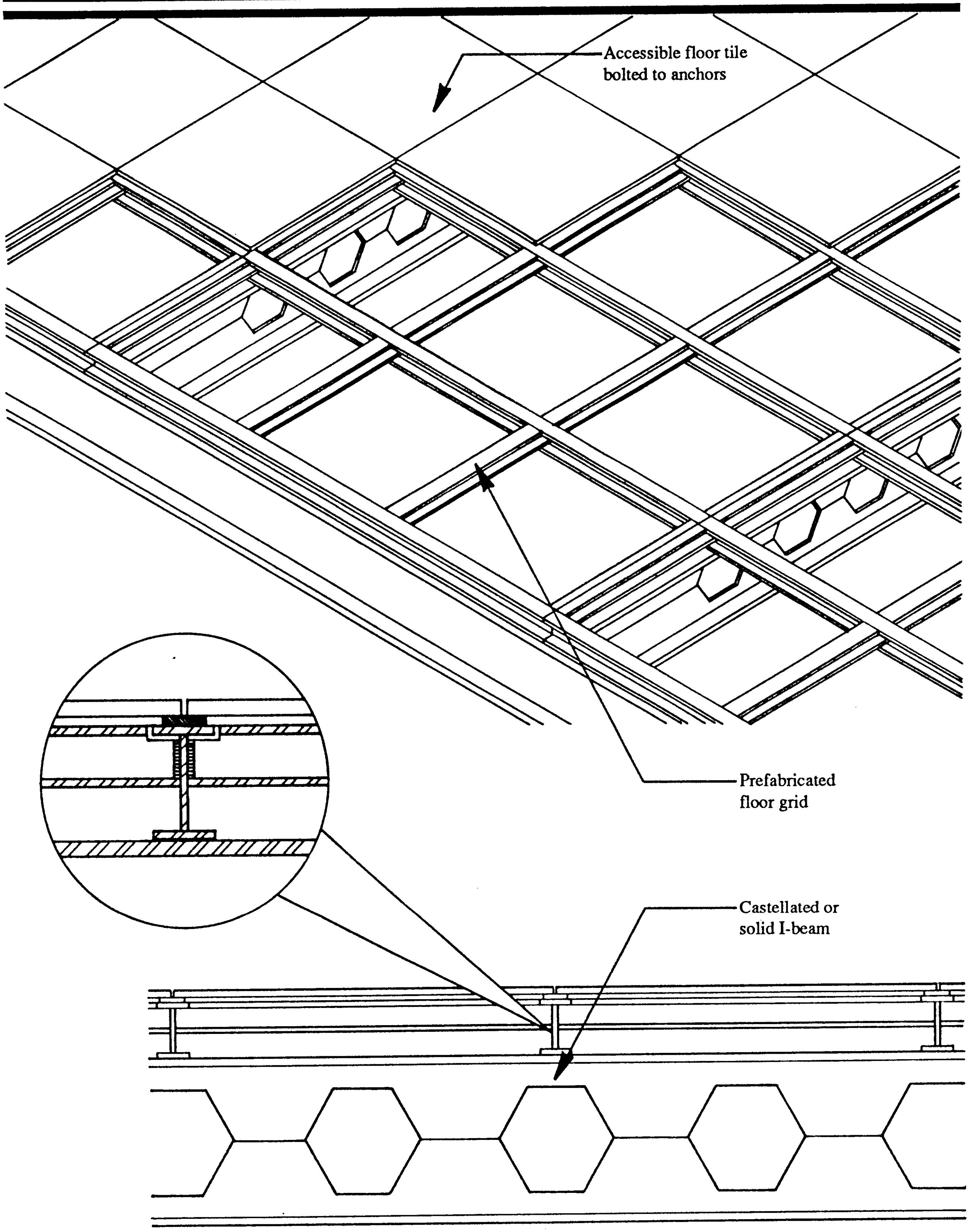
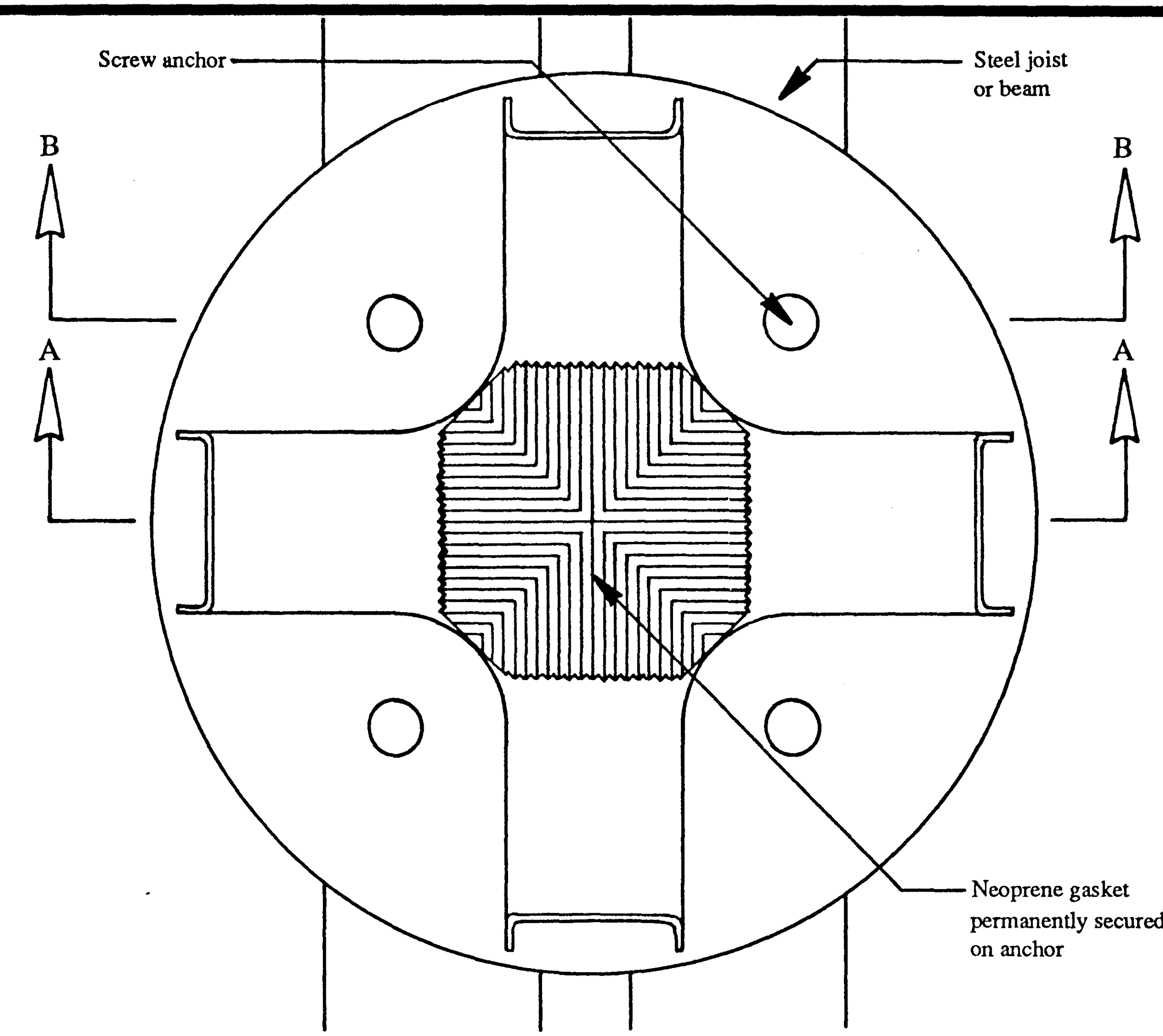


Figure 3:- Economical Model (alternative 3).



Optional floor anchor - plan.

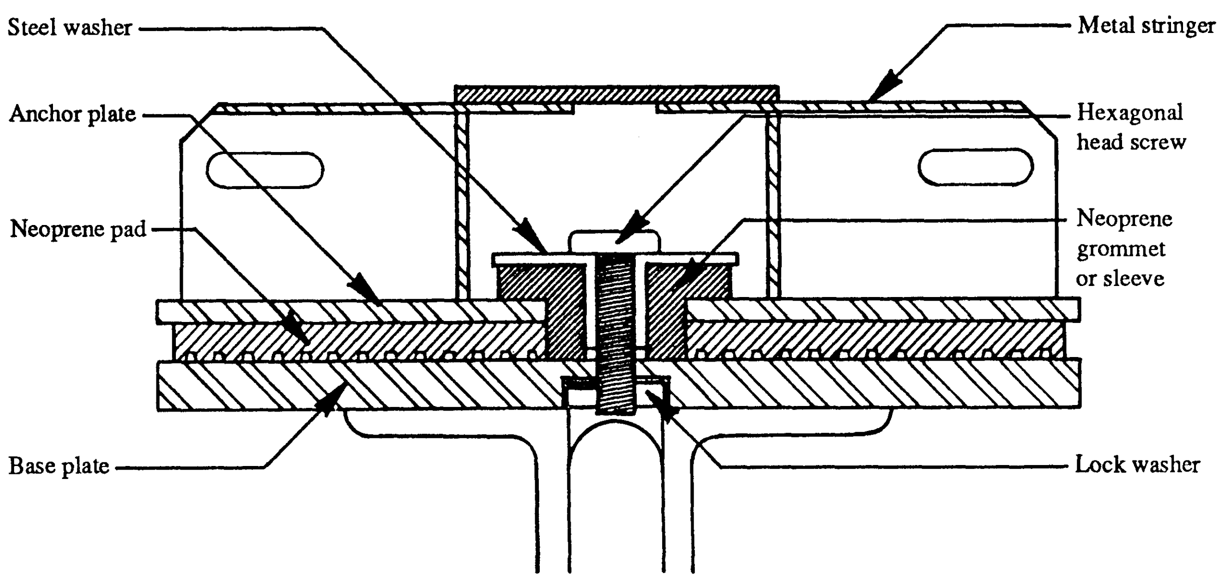


Figure 4:- Optional floor anchor - section A-A.

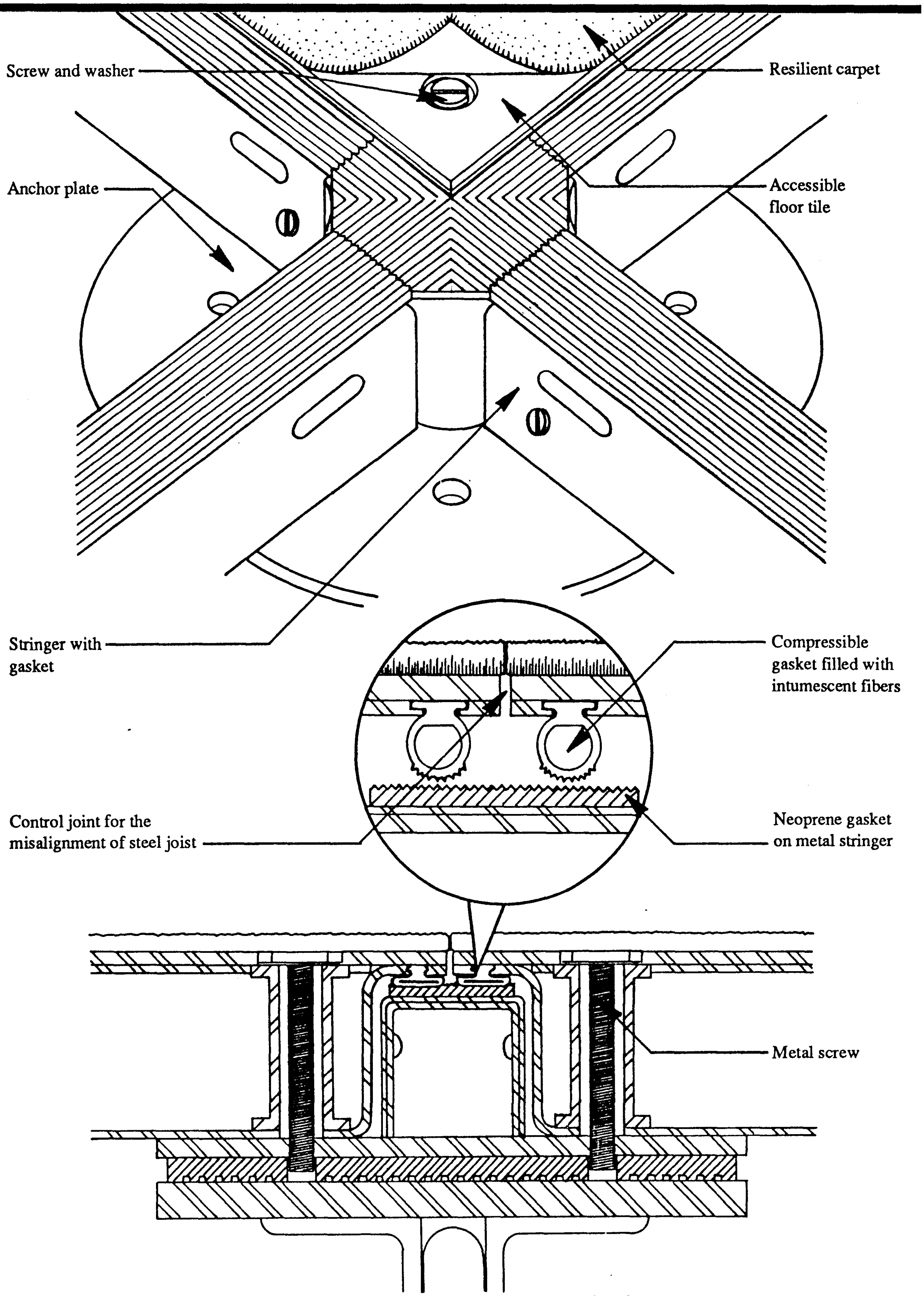


Figure 5:- Optional floor anchor - section B-B.

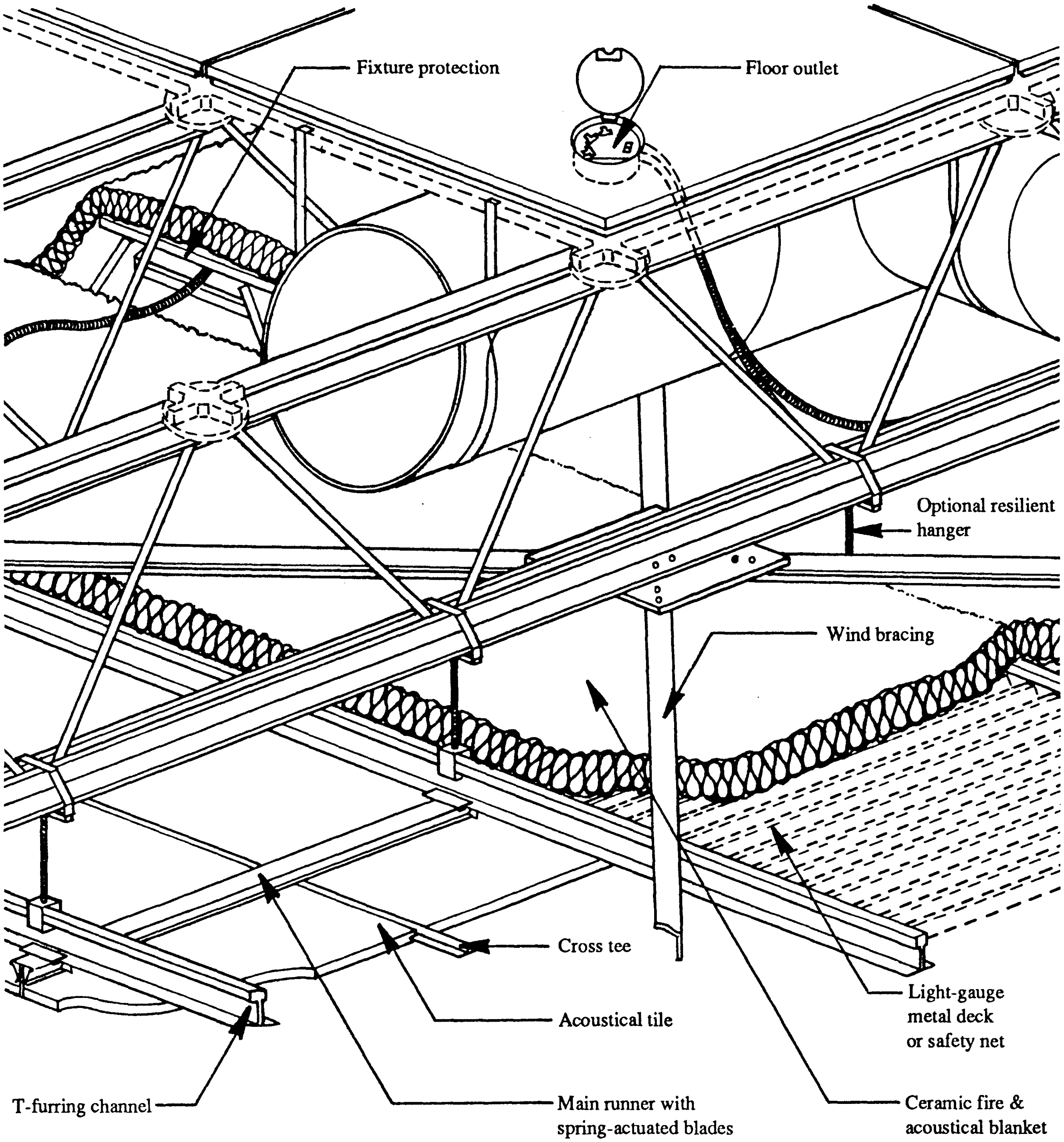


Figure 6:- Economical Model with fire-rated ceiling.

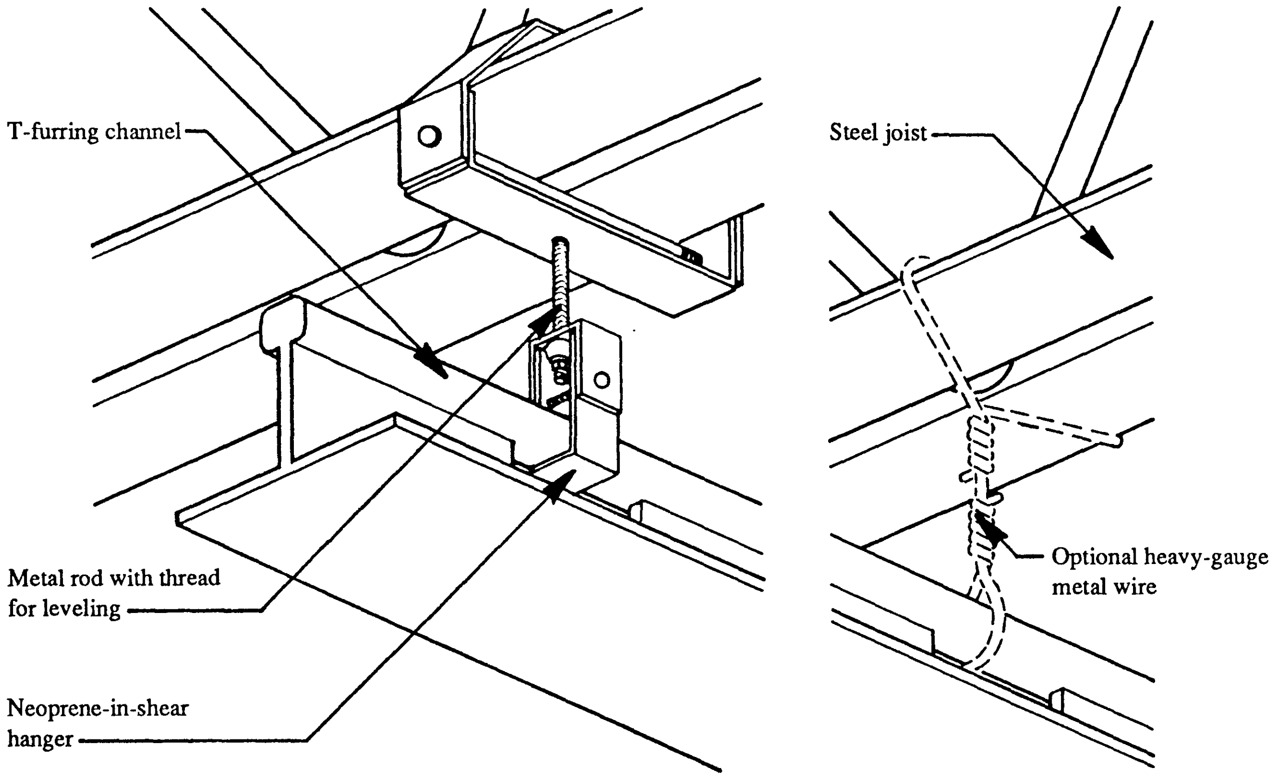


Figure 7:- Resilient hangers.

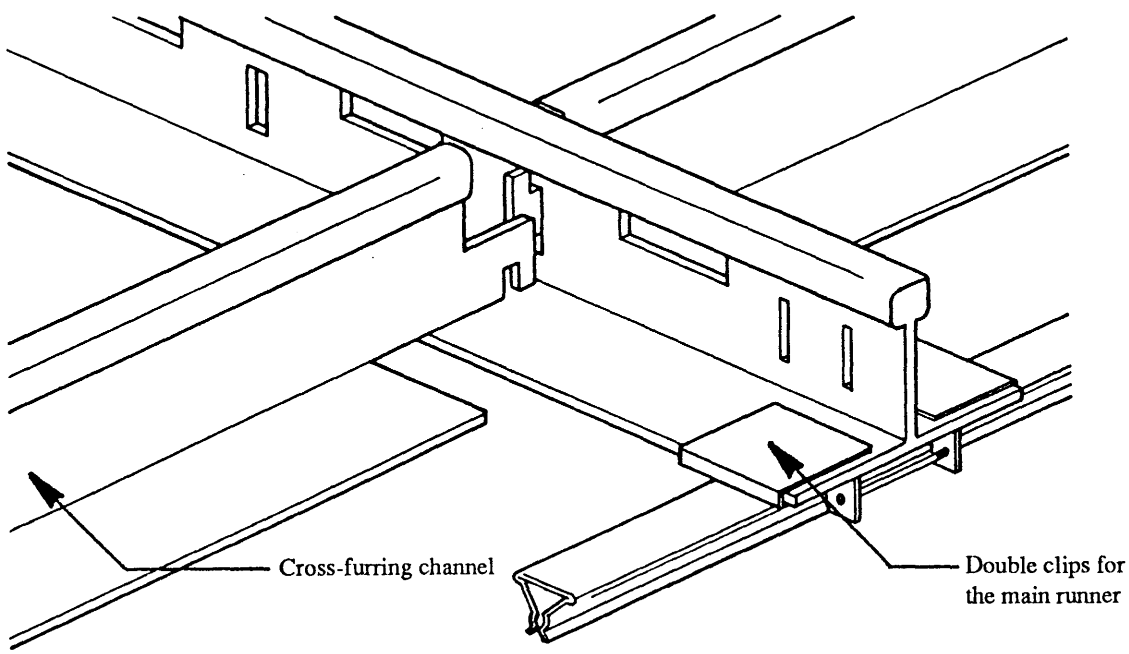


Figure 8:- T-furring channel and cross-furring channels

Economical Model: -

Open-web steel joists or beams are laid at a maximum of 4'-0" on centers to achieve standardization. Non-standardized elements such as floor panels, concrete on metal decks and pressure-impregnated fire-retardant treated plywood on metal deck can integrate with this method for a variety of architectural floor plans. Any seam between the standardized tiles, the conventional slabs or the curtain walls should be caulk with fire-stop sealants. The sealants should have the added benefits of resisting dust and water penetration. Floor panels with conventional concrete or plywood on metal decks are designed on the same level to avoid the use of stairs or ramps. Steel joists can be designed with different spanning as long as the spacing and joist depth are uniform throughout the floor plan. If open area is provided on site, steel joists could be placed on the ground with equal and appropriate spacing and on temporary supports. All the joists are welded to bridgings before lifting to save the amount of crane time and to speed up the erection (Figure 1). The end-supports of this method can be combined with latticed girders, vierendeel girders, castellated beams for electrical and mechanical penetration.

With bar joists laying perpendicular to the floor slabs, horizontal bridgings and cross bridgings are installed in between steel joists for lateral stiffness. Cross bridgings are expensive to install than horizontal bridgings and should be limited to their number. In any case, the ends of all bridging lines terminating at walls or beams must be anchored to the top and bottom chords. Cross bridging can be omitted only for area required the installation of oversized mechanical ducts. Trussing or cross-bracings are also installed below steel joists to resist lateral wind and seismic loads. Cross-bracings could be designed with gusset plates. Cross-bracings should be installed in all the edge bays or along the perimeter of the floor framing to withstand the highest shear in the horizontal structure. Cross-bracing could be used in each floor or at every second or third floor, if the stiffness of the columns is adequate to transmit the wind forces over such height intervals. This bracing should connect all the horizontal elements to the vertical bracing system without appreciable deformation. The vertical bracing system can be shear panels, moment-resistant connections between the members, or trussing. Temporary cross and horizontal bridgings are often used to ensure sufficient lateral stiffness in the joists. Also, temporary cross-bracings are often used to ensure sufficient rigidity in the plane of the slab, and so are not regarded as superfluous extra cost. The upper chords of steel joists can be tied together with horizontal bridgings without the use of floor anchors, or tied with metal stringers bolted to optional pre-installed floor anchors (see paragraphs below on horizontal bridgings and metal stringers). Both of them can be designed with inverted C-channels. Similarly, the upper chord of each steel joist can be designed with two C-shaped sections laying against each other. With the absence of floor anchors, floor tiles are bolted down to the pre-drilled holes on the upper chords of steel joists.

An alternative bar-joist-like element, with C-shaped sections for the upper and lower chords and a solid-bar-like diagonal inclined at a 45 degree angle to the horizontal plane as an open web, is highly recommended. Cross-furring channels, with inverted C-shaped sections similar to the upper or lower chords, are provided for the upper chords to form a space-frame-like structure (Figure 2). Holes can be pre-drilled on the upper chords for floor tiles without the use of floor anchors. The location of the cross-furring channels is then guided by the pre-drilled holes or pre-welded connections on the upper chords of bar joists. An alternative of this method can be combined with the rolled or welded circular hollow sections, which are commonly used in the lattice structures. The circular sections are used for the diagonals and lower chords with either welded or bolted connections, the bolted connections could be similar to the Mero system with metal spheres and bolts in the conical ends of the members. The bolts of the members are screwed into the boleholes in the metal spheres. These methods have the advantages of their economy in fabrication and installation; however, the triangulations of the space-frame-like structures have less opening for the penetration of oversized mechanical ducts. Also, a designed floor load is limited by the sizes of the members.

Another more costly alternative is to use prefabricated floor grids with steel girders. The cross-furring channels or bridgings of the steel girders can be smaller C, I or T sections with bolted or welded connections. The dimensions of floor grids are controlled by the sizes of the floor tile and the vehicles for transportation. The floor grids are welded to castellated beams, open-web or solid I-beams on the site. However, steel beams can be spaced at least 16 or 22 feet on center with spray-on fire protections (Figure 3). Solid I-beams can be used for low-rised buildings without height restrictions. As in the above examples, holes and gasket can be drilled and installed on the floor grids before their arrival to the site (see paragraph below on solid gaskets). As in the first example, trussing or cross-bracings are installed in all the edge bays and below open-web steel beams to resist lateral wind and seismic loads.

With the installation of cross bridgings or stringers, accessible floor panels can partially (minimum 50%) cover the floor for the installation of ducts or cables, as soon as steel joists or beams are secured to their support with optional pre-installed floor anchors. The optional floor anchors can be welded or glued on the upper chords with epoxy resin (figure 4). To reduce the cost in the first example as mentioned earlier, floor anchors are substituted with two oppositely faced C-channels for the upper chord of each joist. And also, stringers are substituted with horizontal bracings bolted on the upper chords. Floor panels could be installed directly on top of the steel joists with pre-drilled holes and pre-installed gaskets (see paragraph below on gaskets). The stringers and horizontal bracings can be replaced for deterioration due to fire or aging. They are protected from at least 3 hour spray-applied intumescent or subliming coatings (1/16-inch thick). These coatings adhere and harden in a manner similar to paint. Materials such as drywalls, mechanical ducts and ceiling assemblies can be stockpiled in areas covered with floor tiles. Floor panels are supported by the upper chords of steel joists at intervals. Non-standardized floor tiles can be used for the perimeter of the building with standardized tiles laid within the interior of the floor plan. A four-foot tile is recommended for the *Economical Model* with steel joists laid at four feet on centers. Lightweight concrete floor tiles reinforced with wire-mesh are highly recommended for fire safety. Aluminium laminated tile with a lightweight concrete core or an aluminium honeycomb core is also suggested for the floor tile with a minimum of 45 pounds per four-foot tile. Floor tile with aluminium honeycomb core should be sandwiched with a minimum of one layer of fire protective material on its lower surface. The fire protective material could be compressed rock-fiber board or compressed vermiculite board. A floor panel should be designed for dynamic loads from moving carts, construction robots or automated guided vehicles etc. Perforated panel and floor grille for air outlets are not recommended for the *Economical Model*, unless they are directly connected to enclosed mechanical ducts with fire protective floor-plate insert and adjustable dampers.

A circular die-cast aluminium outlet could be used for electrical and communication outlets. The outlets are positioned in the center of one-quarter of the panel so that by simply turning the panel they can be placed anywhere on a two-foot grid. Since the locations of the these outlets change from time to time, flexible conduits should be used for convenience in the relocation of outlets. Each floor-mounted outlet consists of power supplies, telephones, lighting switches and data. Similar to the poke-through outlets, a fire-retardant material expands to close cable-penetrations, traps smoke and vapor during a fire. Ceramic insulation and intumescent caulk etc. are recommended for areas required penetrations through the floor tiles. The underside of floor-mounted outlets can be protected by spray-on insulation undercoating, intumescent mastic coating on the conduit, or heat shields. Panels are designed as temporary working surfaces by delaying the installation of finished layers on panels. Temporary protective coverings can be used on floor panels during the installation of interior finishes. Vinyl asbestos tile and resilient carpet are suggested as the final layers of floor finishes. The bottom edge of each panel is designed with a continuous compressible gasket filled with expansion agents such as intumescent fiber. Solid gaskets are permanently secured to the top of each stringer and the center of each floor anchor. These gaskets should be manufactured with neoprene or silicon rubber reinforced with fabrics such as terylene for abrasion-resistance or fiberglass for fire-resistance. Neoprene is good for watertightness but will melt at high temperature. The inner cords with intumescent fiber work as fire-rated gasket during a later stage of a fire. An optional fire-retardant gasket, such as a woven fiberglass cord filled with intumescent fiber, can be permanently installed adjacent to the compressible gasket mentioned earlier for redundancy. During a fire, the function of these gaskets is to prevent water, fire and smoke penetration through the edges of each panel. The gasket is capable to expand when heated and solidify when exposed to fire. Also, each panel is secured to the anchors with Tuff-Tite or mastic sealed screws at its four corners. These screws compress the compressible gaskets to the solid gaskets to ensure airtightness in the plenum for air return from the ceiling below, and possibly watertightness for fire protection with sprinklers from the ceiling above (Figure 5). With the misalignment of steel joists or during the fabrication of floor grids due to poor workmanship, each screw is allowed to adjusted within a circular shaft, i.e. a shaft designed with a diameter slightly wider than the shank of the screw. And also, a floor panel is designed with an expansion joint around its edges for any unexpected misalignment.

A horizontal fire separation such as an noncombustible bulkhead can be installed in computer rooms, telephone exchanges and plenums with more than 10,000 sq. ft. in areas, depending on the local fire code. Fire resistant rated walls and fiberglass cloth bags can be used to provide permanent or temporary fire stops in the plenums. Fiberglass cloth bags are consist of woven fiberglass bags, filled with mineral fiber and incombustible expansion agents etc.. They are especially suited where changes in penetration are frequent. i.e. to provide fire stops for cable and pipe penetration.

Optional light-gauge metal deckings, or optional corrugated cement tiles and T-furring channels of the fire-rated suspended ceilings should be installed from below as soon as possible at the bottom chords of the steel joists (Figure 6). The installation should be carried out with ladders or scaffolding by adjusting the location of the floor tiles as working platforms. At the same time, the installation of electrical supplies and mechanical ducts could be carried out from the floor above without the temporary placement of floor tiles or from the floor below before the installation of ceiling. It is suggests that the installation should be carried out from the floor above for faster erection as long as the optional metal deckings and T-furring channels of the suspended ceiling are in place for safety. Alternatively, a permanent safety net laying perpendicular on the T-furring channels can be used for safety without the use of metal deck or cement tile. The safety nets can be manufactured with nylon or polypropylene mesh. To further reduce the installation time, the safety net can be sandwiched with a layer of ceramic fiber or similar type of blanket on top for fire and acoustical isolation. The upper surface of the blanket can be covered with a foil-reinforced-kraft facing for abuse resistant (see the paragraph below for ceramic fiber blanket). The concept is similar to the "Top-Down" construction for speeding up the construction time. Mechanical ducts running parallel to floor joists are supported by stringers or cross-bracings; consequently, mechanical ducts running peripendicular to joists are suspended from the steel joists by passing through the open webs with appropriate joist depth and spanning. Additional cross-bracings can be used for areas required extra duct hangers. Two-zone service runs in two planes by allowing the mechanical ducts suspended above electrical and communication cables with hanging rods or metal plates. In-line suspended fans or unit heaters should be suspended with vibration-isolation hangers.

As mentioned earlier, optional light-gauge metal deckings or optional corrugated cement tiles with ceramic fiber blanket are supported in between T-furring channels, by gravity or secured by spring clips in earthquake countries, except for the area with recessed lights, grilles and diffusers. Metal deckings or cement tiles can be cut with a portable circular saw if it is required for the particular layout. It is then covered with one or two layers of ceramic fiber blanket for fire safety and acoustical isolation. Ceramic fiber blankets can be wired, pinned, stapled or taped into place. A metal or cement deck is designed to prevent heavy objects from accidentally penetrating through the ceiling from the floor above, and also serves as a temporary catwalk for the installation of electrical cables and mechanical ducts from the same floor above. As mentioned earlier, ceramic fiber blankets sandwiched with safety nets can be permanently installed perpendicular on the T-furring channels without the use of metal decking or ceramic tile. The safety nets are then tied to the T-furring channels with metal wires from the floor below. In this case, temporary catwalk is provided with plywood supported in between steel joists or furring channels.

Recessed grilles, diffusers and troffer lights should be mounted prior to the installation of ceiling tiles. Fire-rated dampers in the supply or return ducts that are activated by fusible links can close against a fire spread through the duct openings. Each damper is constructed with 22 gauge galvanized steel protected on both surfaces with ceramic blankets and with a fire resistance rating of 3 hours or less. Mechanical openings can be designed with diffuser pans and ceramic insulating blankets to give additional fire protection. No damper is required if area of opening is less than 20 sq. in. and not of aluminium or class 1 duct. Light/air fittings with air supply boots and dampers attached to the lighting fixtures can be used. Return air to the ceiling plenum may be gained via the lighting fixtures with localized heat at the light source. Separate air outlet units or light/air fittings are connected to main duct runs by use of flexible ducts, allowing for ease of relocation in case of office layout alternations.

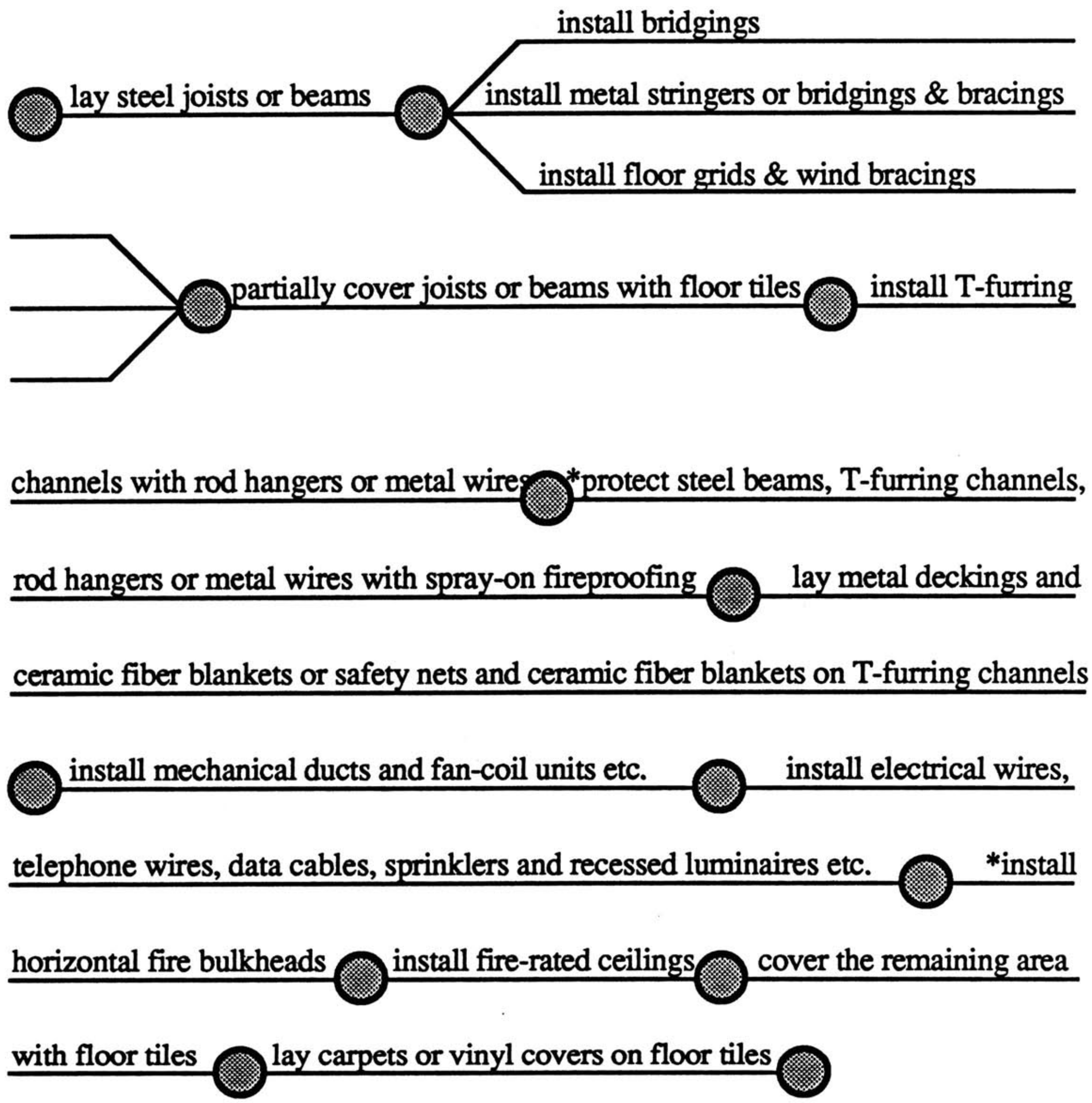
Light fixtures designed to coordinate with the ceiling tile unit are designed to alternate in any position with the tile. Sufficient length of flexible cable with plug-in type connection is allowed on each fitting so as to give the necessary range of movement. This conventional system allows for ready removal or addition of a light fixtures. The steel housing of the recessed lighting fixtures is protected with 5/8" gypsum boards, compressed rock fiber boards or compressed vermiculite boards. Fixture protection is achieved by cutting fireproofing materials into 3 pieces, trapazoidal in cross-section, with openings at both ends to release heat from a recessed lighting fixture. Fixture protection should provide a minimum of 1/2 in. clearance between the top of the fixture and the enclosure. The top piece is secured to the side piece with galvanized steel wires at three locations per side. The enclosure is then covered with ceramic fiber blankets, except at the end of the enclosure. All wiring should be in conformity with the electrical code for safety and power supplies are enclosed in flexible conduits. Moreover, communication and electronic cables are supplied from vertical risers to floor outlets as in the case of power cables by running on top of the ceramic fiber. All types of material using in the plenum should be non-combustible and non-toxic to human.

Fire-rated acoustical ceiling tiles are suspended by means of a special concealed accessible suspension system. T-furring channels are suspended from the bottom chords of steel joists or floor grids with resilient galvanized steel rod hangers spaced at a maximum of four feet on centers. To reduce the cost, rod hangers can be substituted with heavy-gauged metal wires, as long as their diameter and spacing are strong enough to support the ceiling assemblies below (Figure 7). The T-furring channels, galvanized steel rod hangers and steel joists can be protected from fire with spray-on fireproofing, before the installation of ducts, trenches and acoustical ceilings. T-furring channels are 12 ft. long, spaced not more than 4 ft. on centers and not more than 10 in. from the wall. They can be interlocked together by optional cross or secondary T-bars, perpendicular to the T-furring channels, at regular intervals or at the end of each decking. Main runners are installed perpendicular to the T-furring channels from below and clamped to the carrying channels by channel clamps (Figure 8). The main runners are comprised of parallel opposing spring-actuated blades which are outwadly flared both upward and downward. Cross tees are splined on each side for engagement with kerfed acoustical tile and are provided with two vertical holding tongues at each end for retractable engagement with the main runners. Holding tongues have locking dimples which snap into the upper flared section of the main runners. All cross tees have slots in the top of the fin at each end for inserting a hooked access tool for tile removal. This type of ceiling tiles has limited amount of accessibility to ensure fire integrity of the ceiling. The acoustical tiles can be heavy semi-rigid foam-like borad. With adequate fire protection and acoustical isolation, ceramic or similar types of blankets can be omitted to simplify the installation. Maintenance and modification should be done with fully qualified personnel and approved by the local fire department for safety. The concept of the *Economical Model* is to increase the flexibility of the accessible floor and at the same time, reduce the flexibility of the accessible ceiling below. The layout of the electrical and mechanical outlets is changed more often than the ceiling layout, especially in an electronic office. The modular size of the ceiling grid is determined by a combination of many factors. Dimensional size of the building structure, proposed individual office size, materials associated with the ceilings, and partitioning of floor covering can all affect the modular size. In this case where the nominal 4-ft module is selected for the ceilings to coordinate with the dimension of the floor tiles.

A demountable ceiling-to-floor partitioning system is suggested to be used for area required privacy. Also, different tenants can share with the same floor with interior partitions for security and acoustical separation. Interior partitions could be hung from the ceilings with pin or slot-plate connectors suspended from the main runners. This supported the partitions at the node points on the 4-ft module with slip joint at skirting level. Partitions are to be free to move from side to side in relation to each other with slip joints at the vertical junctions. Doors and their frames are installed on the floor and slide up and down in relation with the partitions. All the joints should be carefully sealed with mechanism such as compressible vinyl gaskets for acoustical isolation. The partitions stop at suspended ceiling level to prevent the transmission of sound between offices, and they can be lined with gypsum boards and sound attenuation blankets to improve acoustical isolation. Glass and mullions can be used for area required visibility.

Solid ceilings with gypsum boards or fibrous plaster on metal laths are primarily used in special areas. This type of ceiling, used in public spaces, storage areas, fire protective spaces and security rooms, has a much lower acoustic and sound absorptive quality than suspended tile ceilings. It is wise to isolate the more rigid ceiling systems from slabs, walls and columns to prevent damage to these elements due to building movement.

Economical Model (typical construction sequence) *optional sequence



Limitations:-

*Careful workmanship is required during the installation and renovation of ceilings to ensure the fire integrity of the floor. Accessibility is limited to any area of the ceiling for quick service work. A lightweight concrete panel is highly recommended for fire safety; moreover, a fire protective layer can be installed on the bottom face of the tile for protection. i.e. a gypsum cement board or a compressed vermiculite board. Fire protective sprinkers in the acoustical ceilings are recommended for floor-to-floor fire protection.

*With the absence of a permanent floor slab, there are limitations on the data cable and floor-to-floor security. Fiber optic cables (refer to chapter 6), microwave scanners, infrared motion detectors and are highly recommended for buildings required security.

*Deflection will be slightly higher than concrete slab design. Care must be taken when steel beams support large open floor areas free of partitions or other damping sources. All optional floor anchors sandwich 3/16" neoprene pads which work as dampers with floor tiles bolted to the 1/4" base plate (Figure 4). Floors tiles are designed to sit on continuous compressible gaskets. With the absence of a permanent concrete slab, interior walls, partitions and groups of people are excellent sources of dampers. Increasing the stiffness of the support beams will lower the vibration of the floor.

Advantages:-

*A faster construction cycle is achieved with floor panels used as temporary working platforms for the installation of interior finishes and exterior claddings. Floor panels could then become a permanent decking covered with floor finishes. No concrete is poured on the site or off the site; consequently, time is saved on pouring and waiting for the concrete to cure, especially in the freezing weather. Accessible floor tiles are designed to lay directly on the top of steel joists; therefore, no floor leveling is required.

*The *Economical Model* is basically cost slightly higher than the conventional types of construction with concrete on cellular decks. With the cost of labor increasingly faster than the cost of building materials, the *Economical Model* has the capability to compete with the conventional construction because of its faster construction cycle. This will compensate from the additional spending on pre-installed floor anchors, accessible floor tiles with gaskets and fire-protective stringers etc.. Although the composite design in conventional construction is intented to save 20-30% of steel, the design calculation has to add up the dead load of the composite concrete planks or decks. An accessible aluminium tile weighs less than 3 lb/sq. ft. compared with 35-40 lb/sq. ft. for lightweight concrete deck. Horizontal cross bracing can combine with vertical bracing to reduce the weight of steel per square foot. As a result, a cheaper footing or foundation can be designed to carry a lighter moment resisting or braced frame on top.

Chapter 4 An Outline of the New Construction Technique and Design Strategy (Part 2)

"The Supreme Model has the design capacity for carrying more floor load ············ a permanent fire and security separation between floors by using a composite concrete slab."

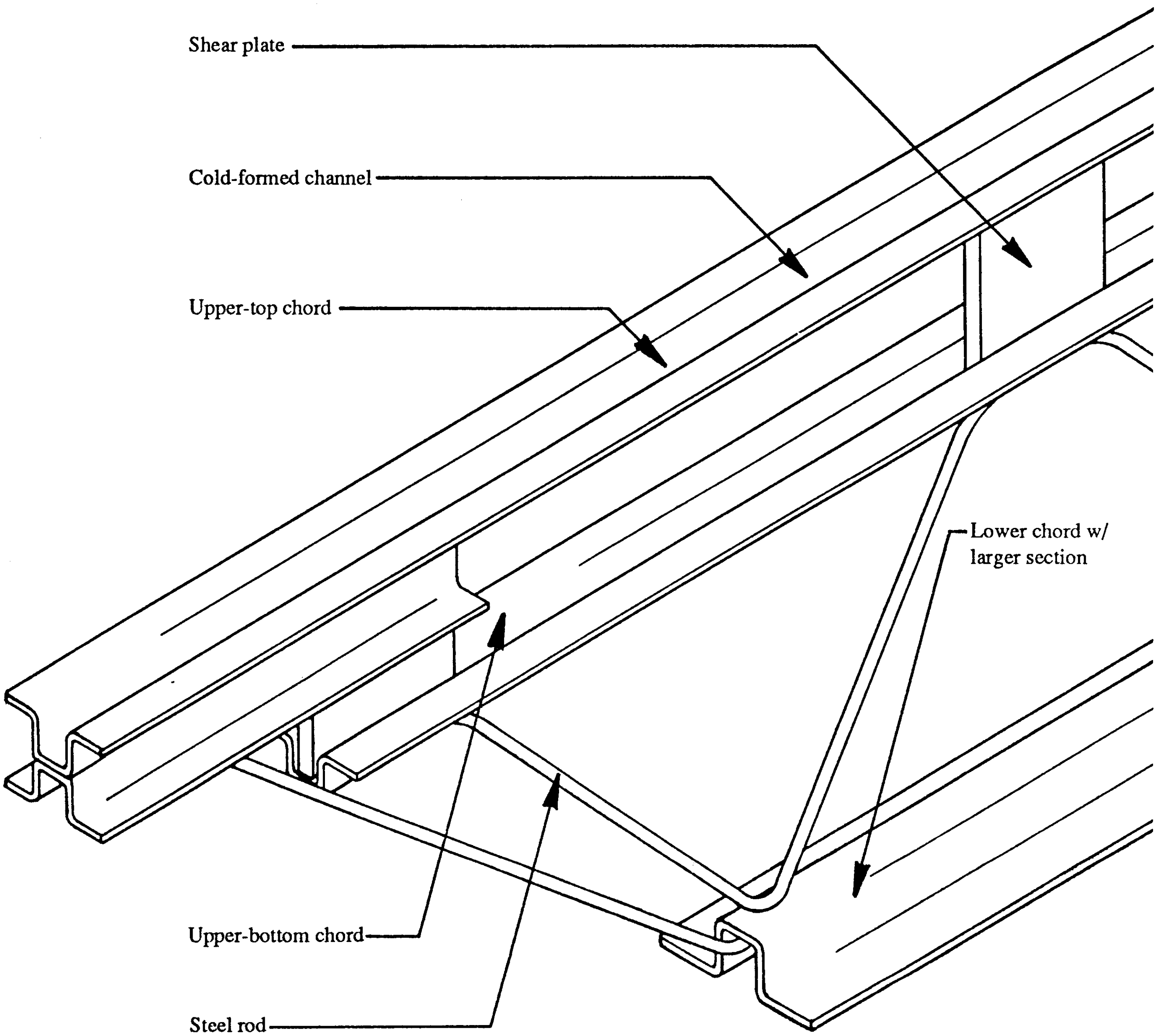


Figure 9a:- Composite Web Joist - modified bar joist.

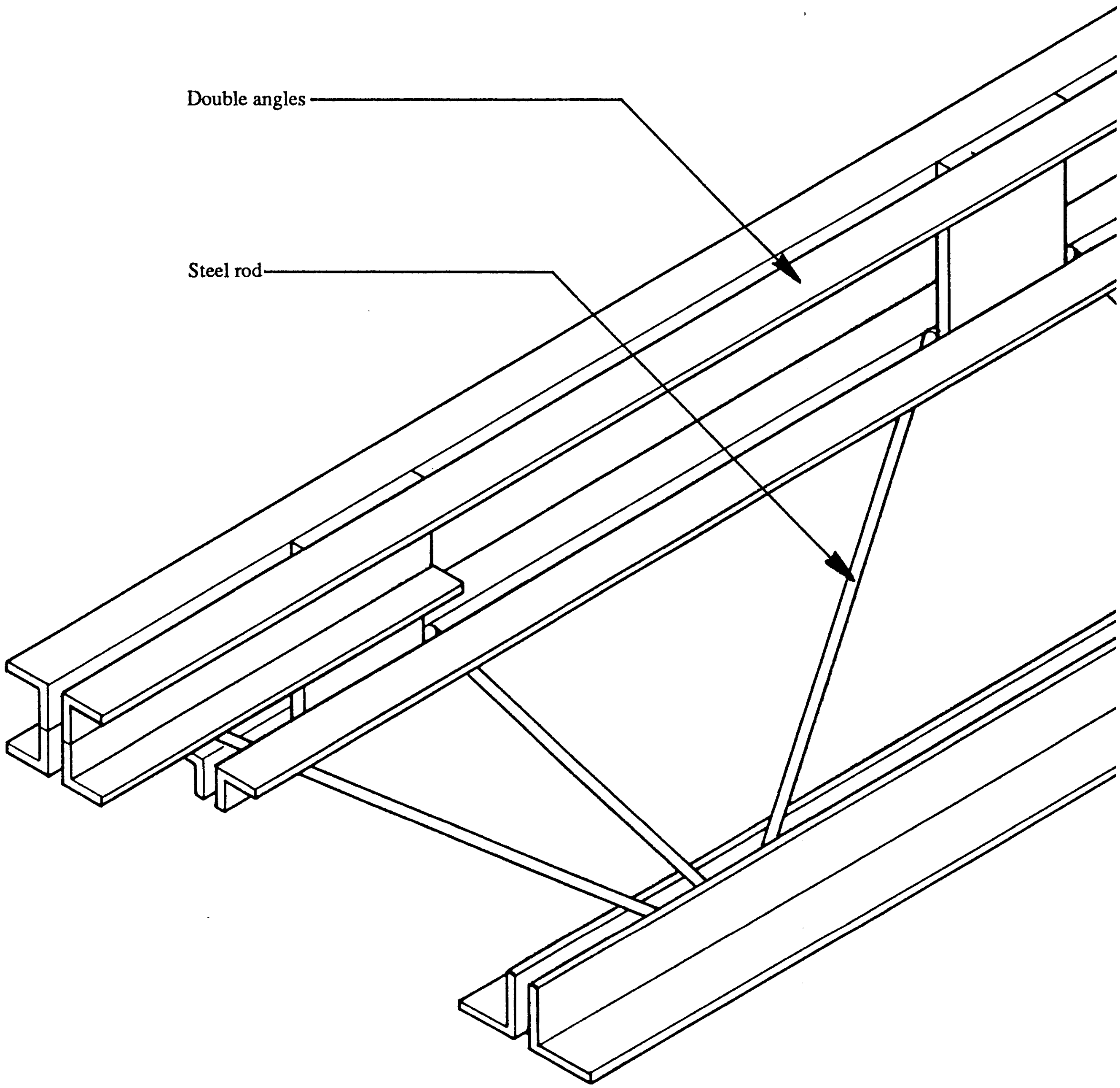


Figure 9b:- Composite Web Joist - modified bar joist.

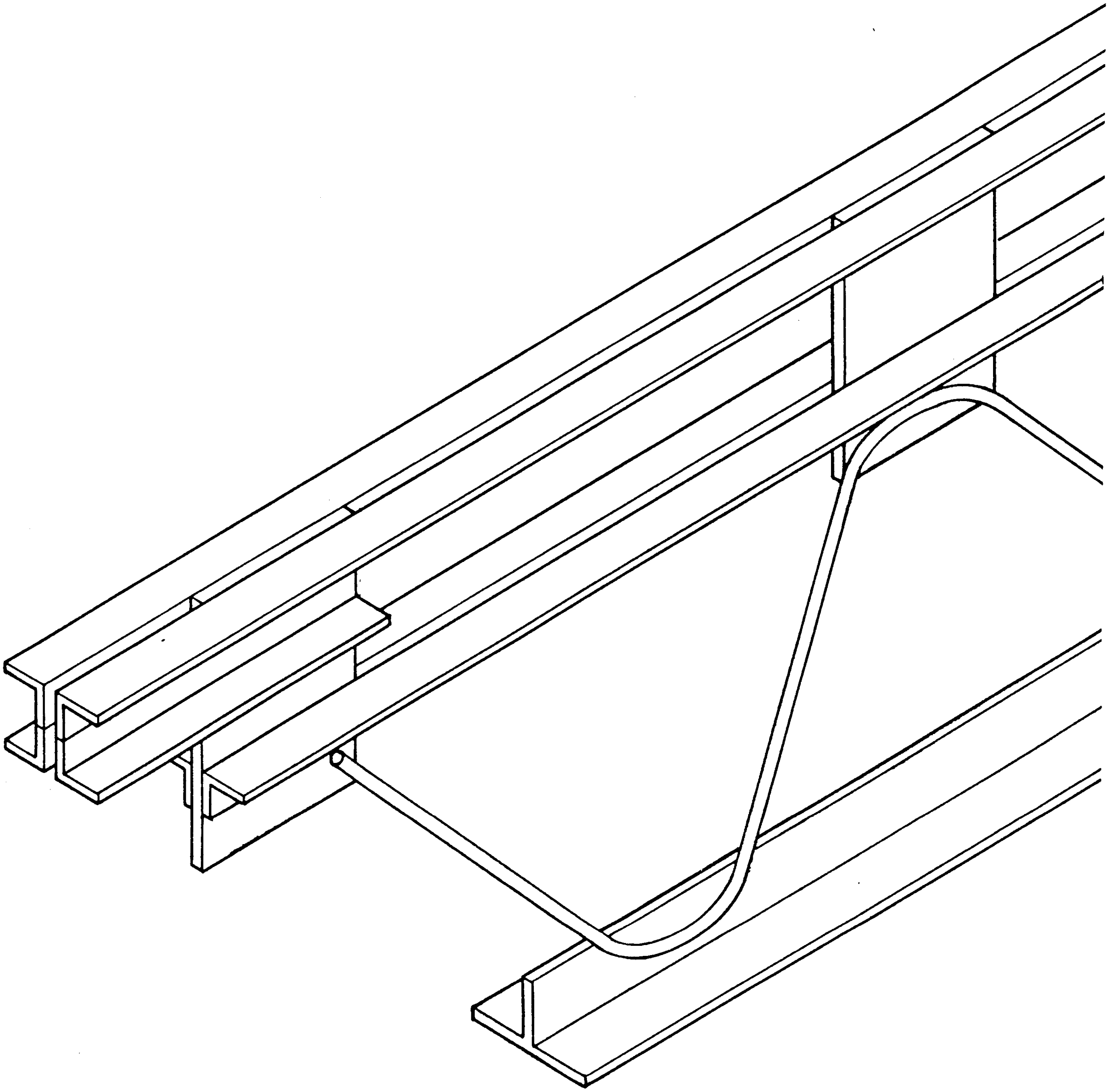


Figure 9c:- Composite Web Joist - modified bar joist.

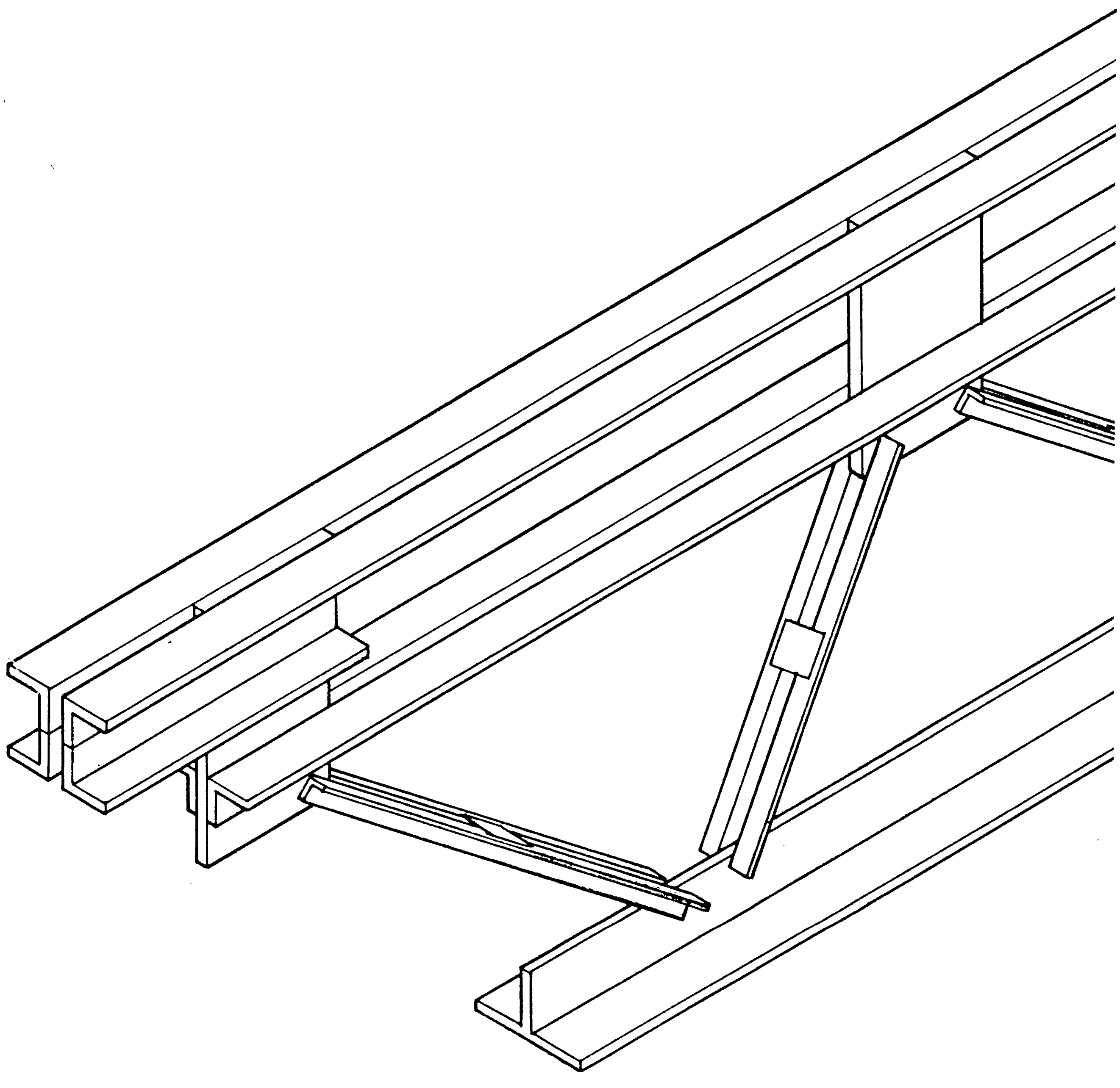


Figure 9d:- Composite Web Joist - modified bar joist.

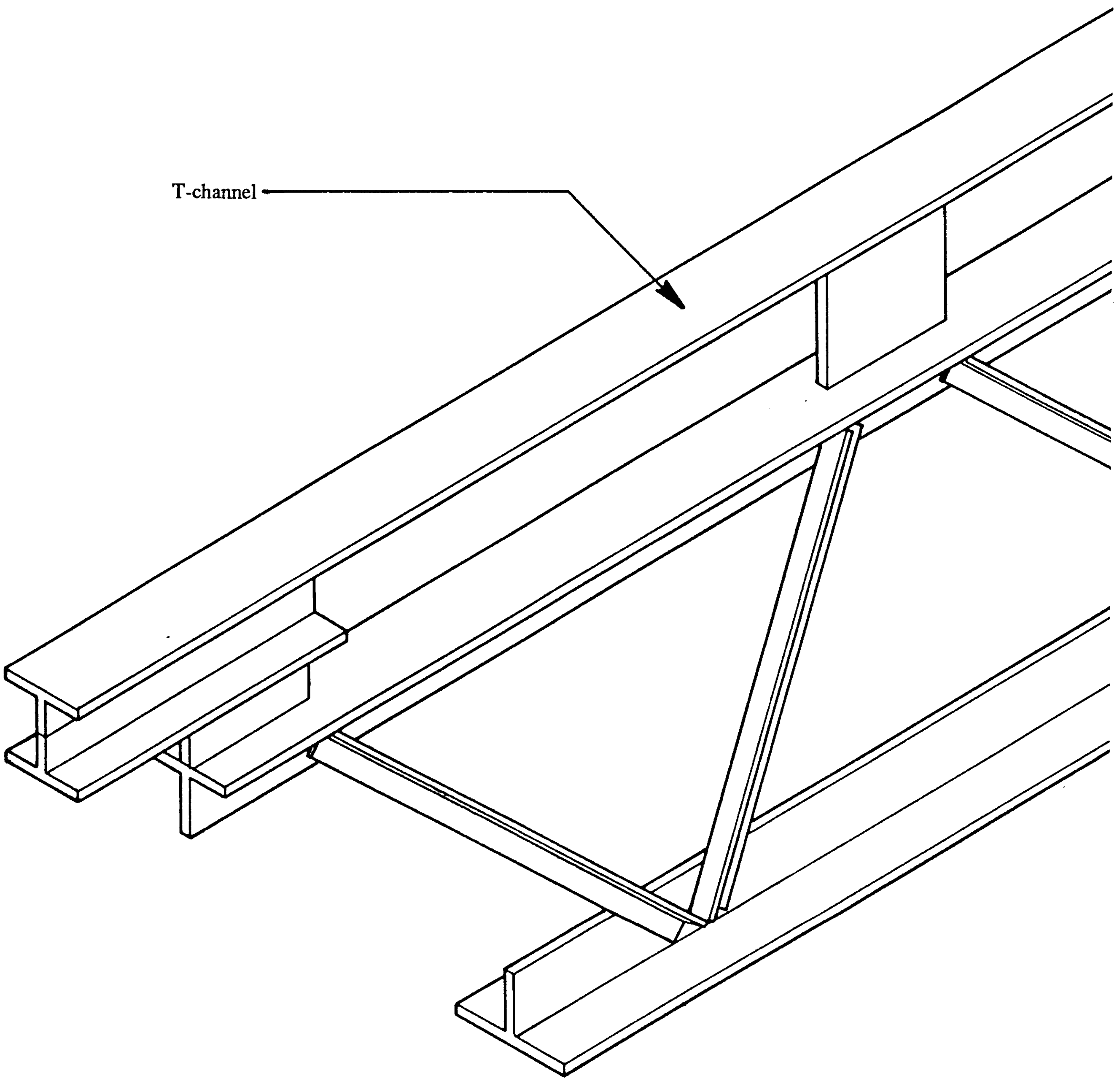


Figure 9e:- Composite Web Joist - modified bar joist.

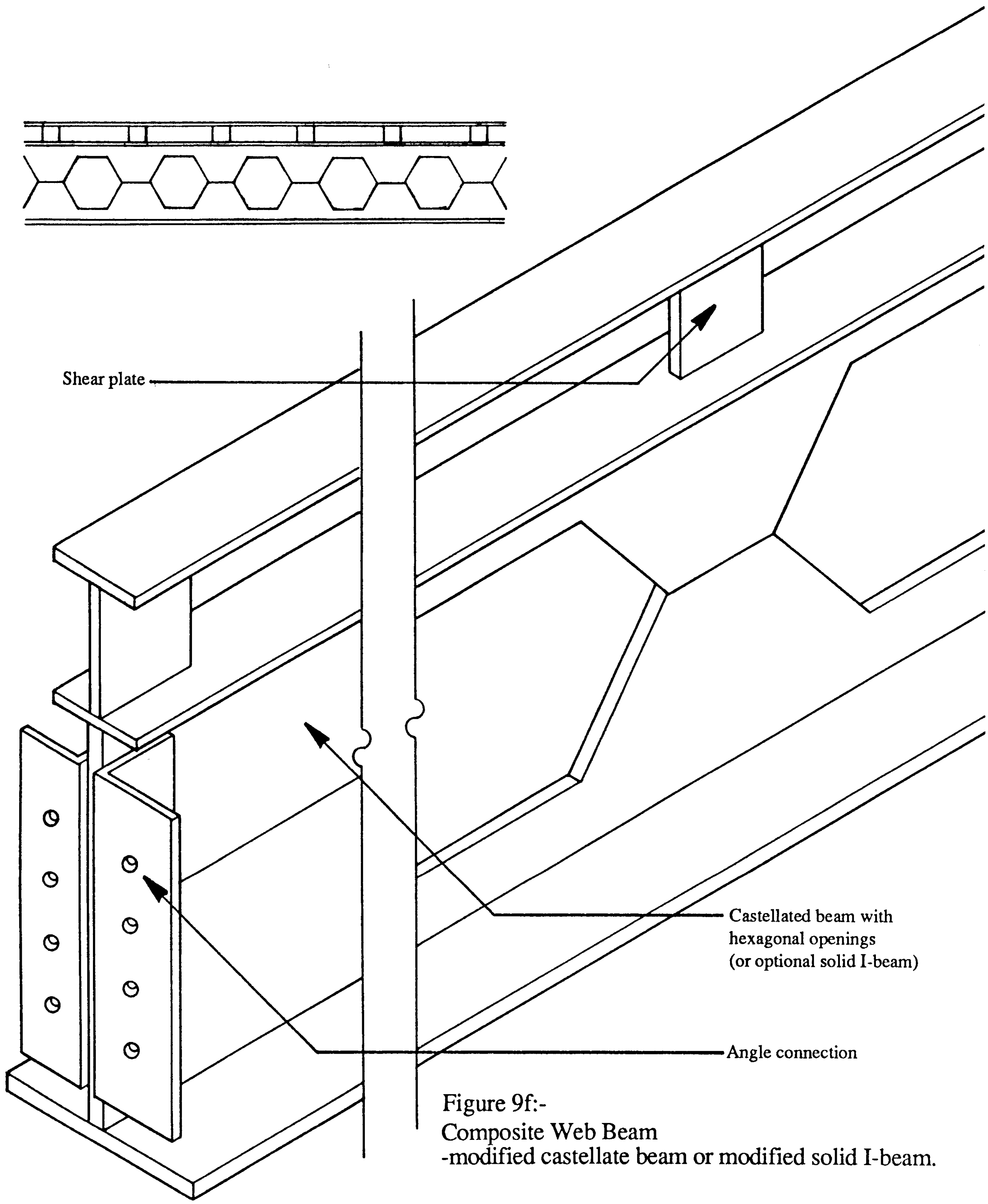


Figure 9f:-
Composite Web Beam
-modified castellate beam or modified solid I-beam.

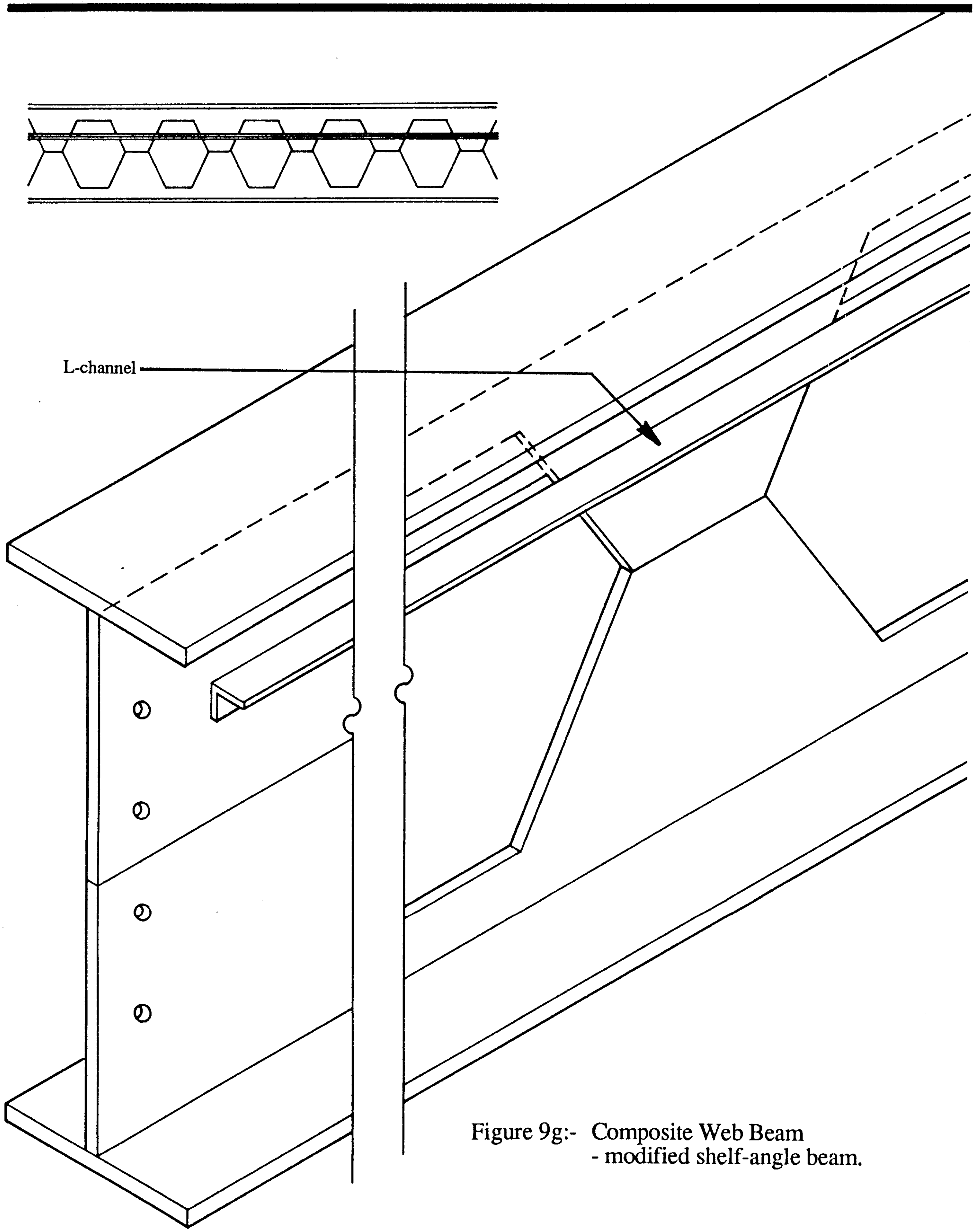


Figure 9g:- Composite Web Beam
- modified shelf-angle beam.

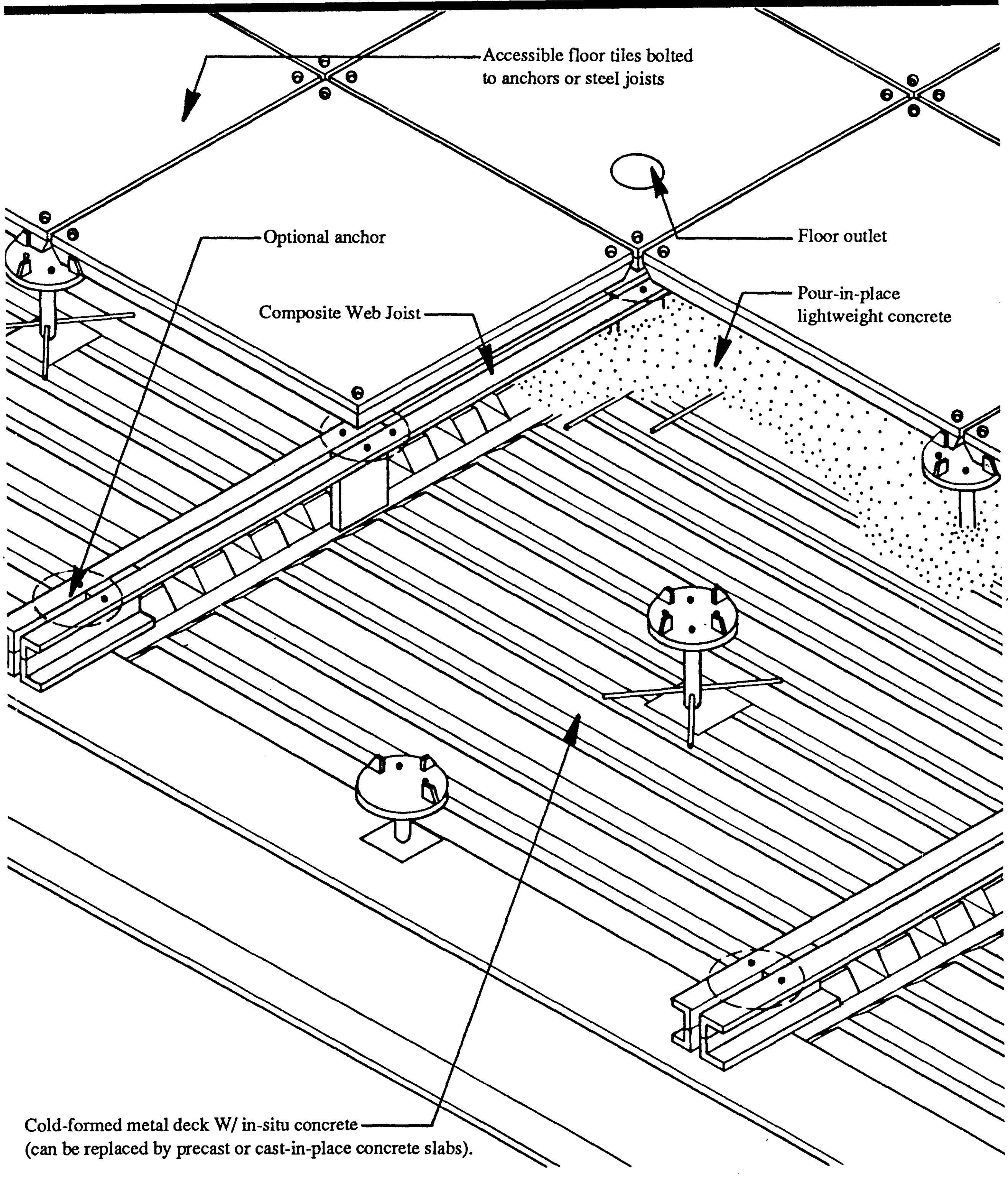


Figure 10:- Supreme Model.

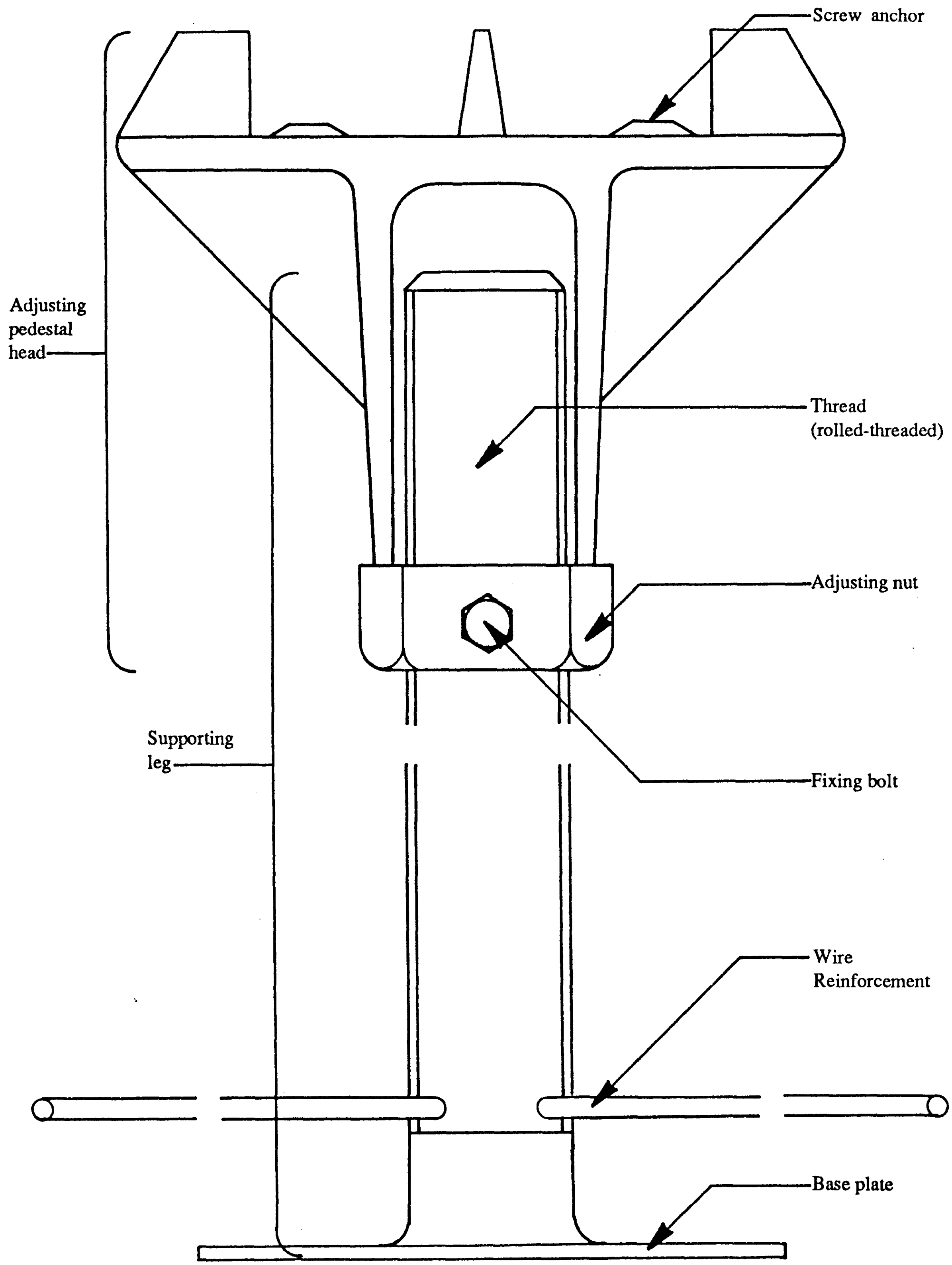
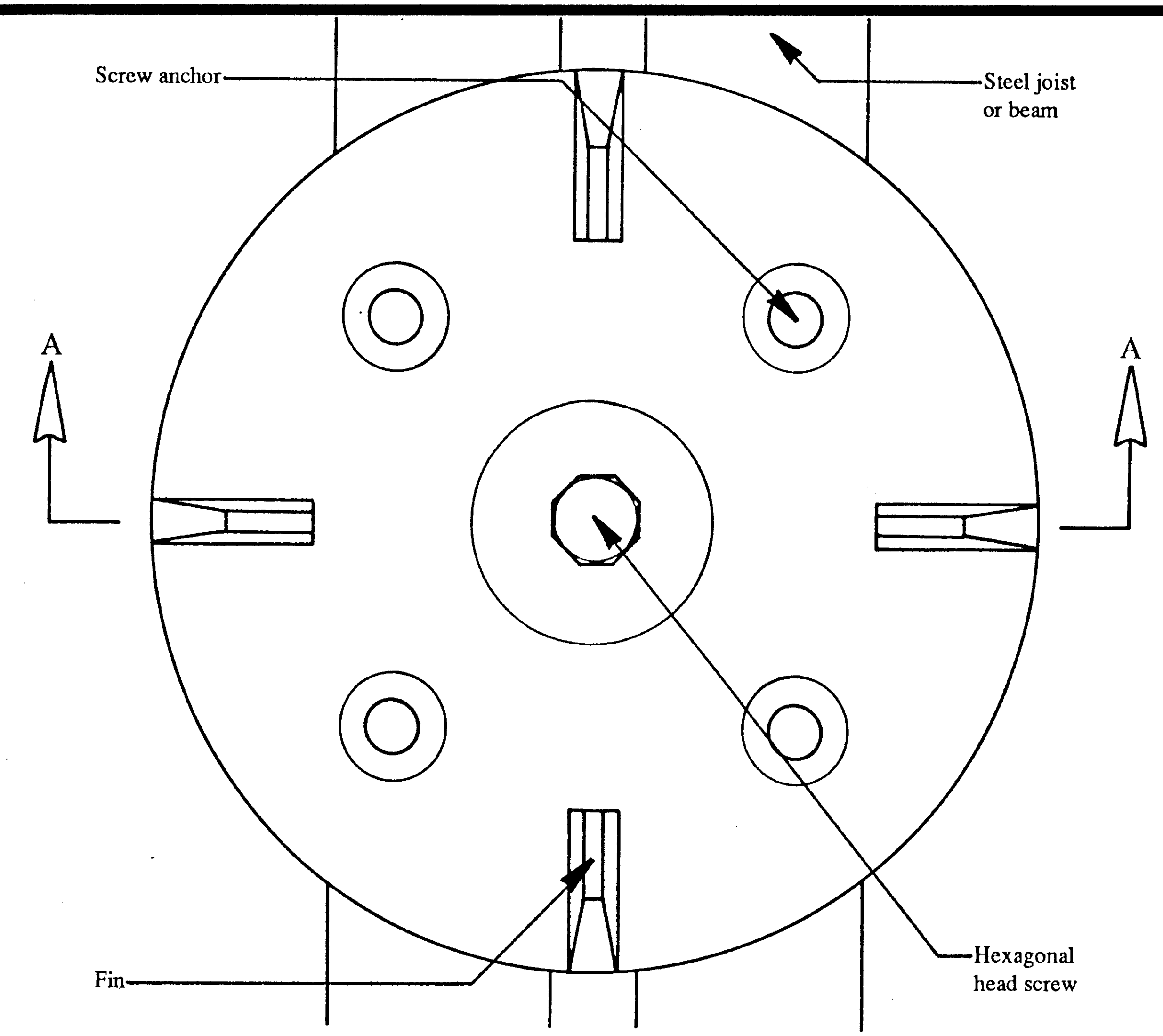


Figure 11:- Pedestal with base plate & wire reinforcement.
- for composite concrete slabs with metal decks.



Optional floor anchor - plan.

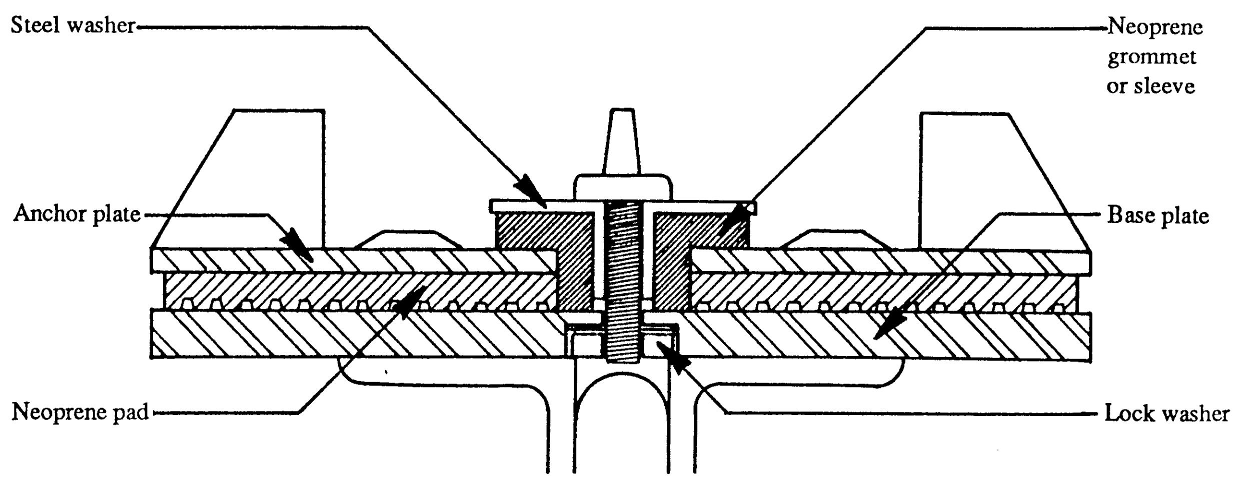


Figure 12:- Optional floor anchor - section A-A.

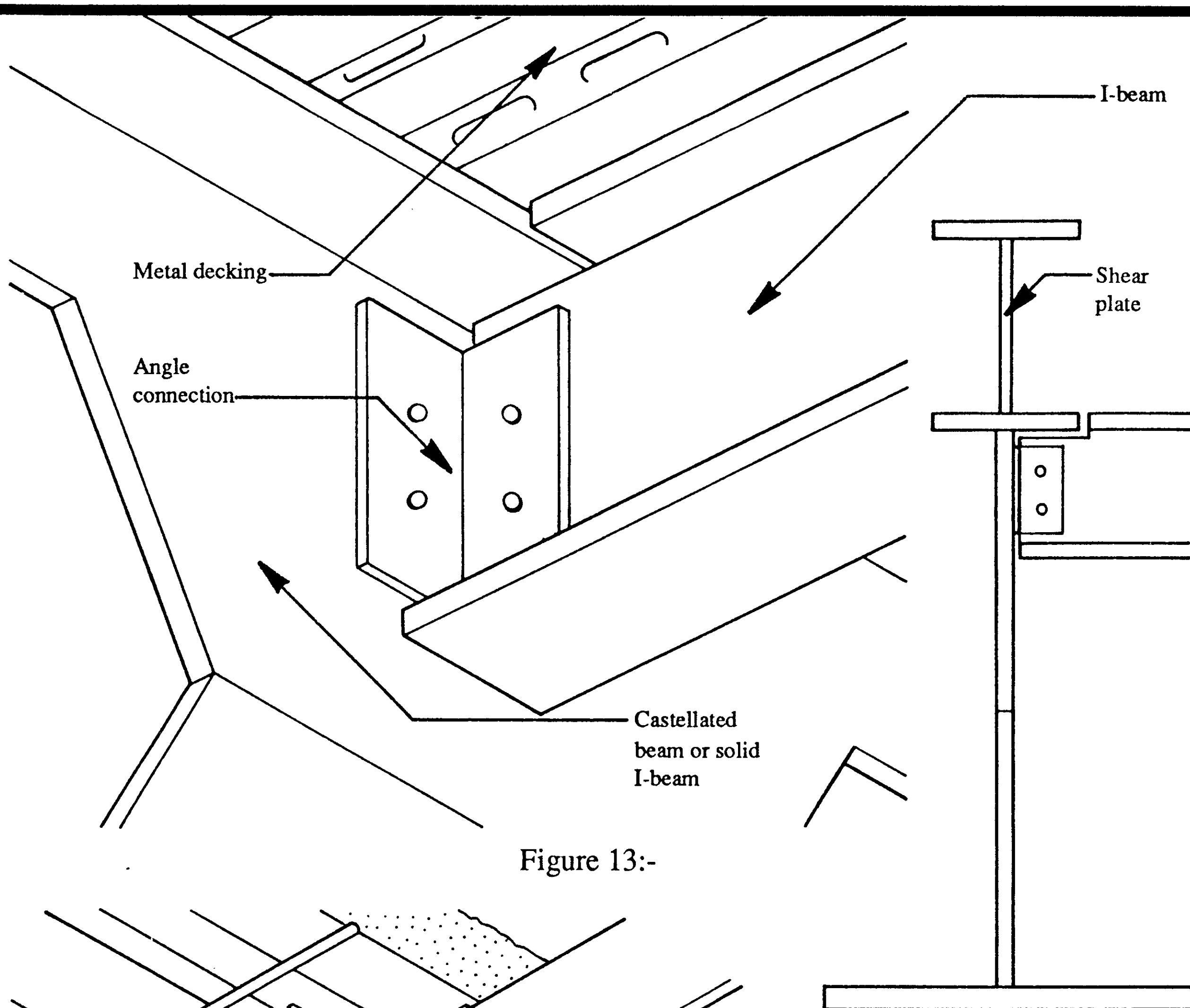


Figure 13:-

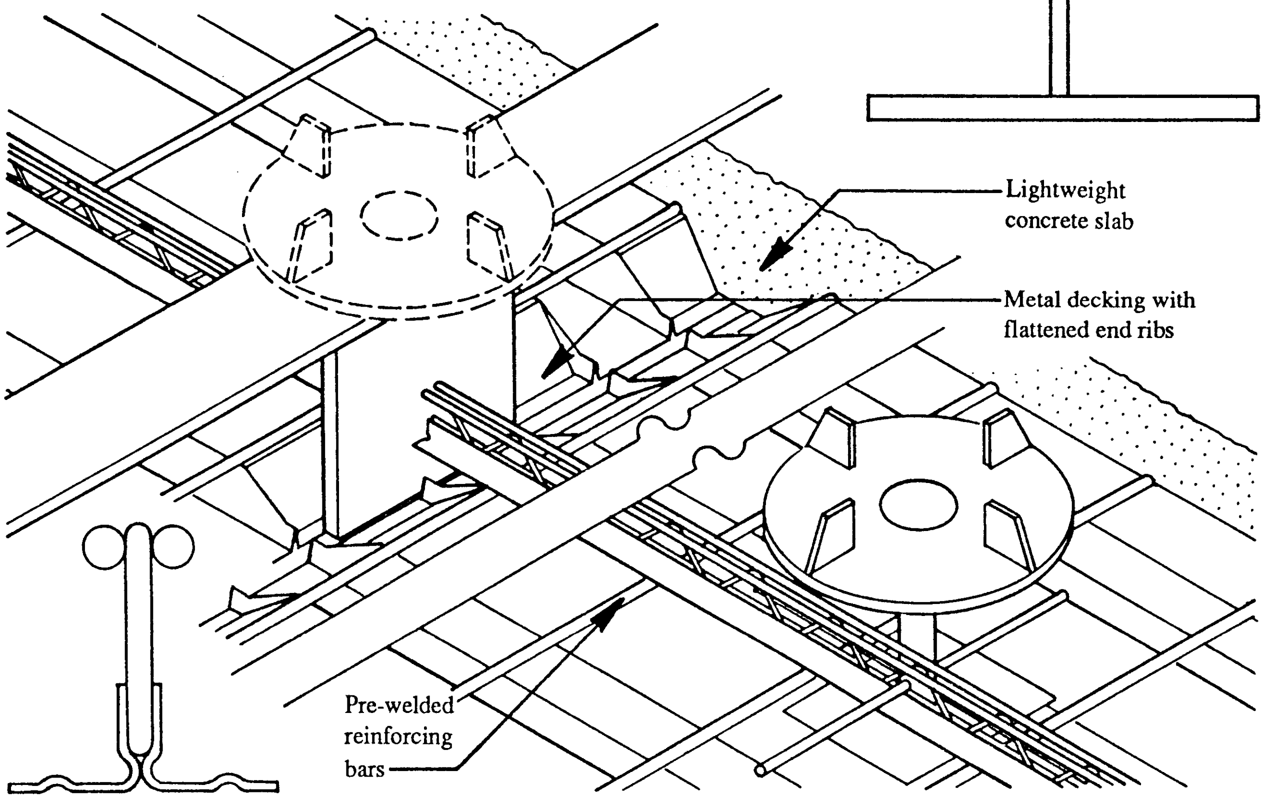


Figure 14:-

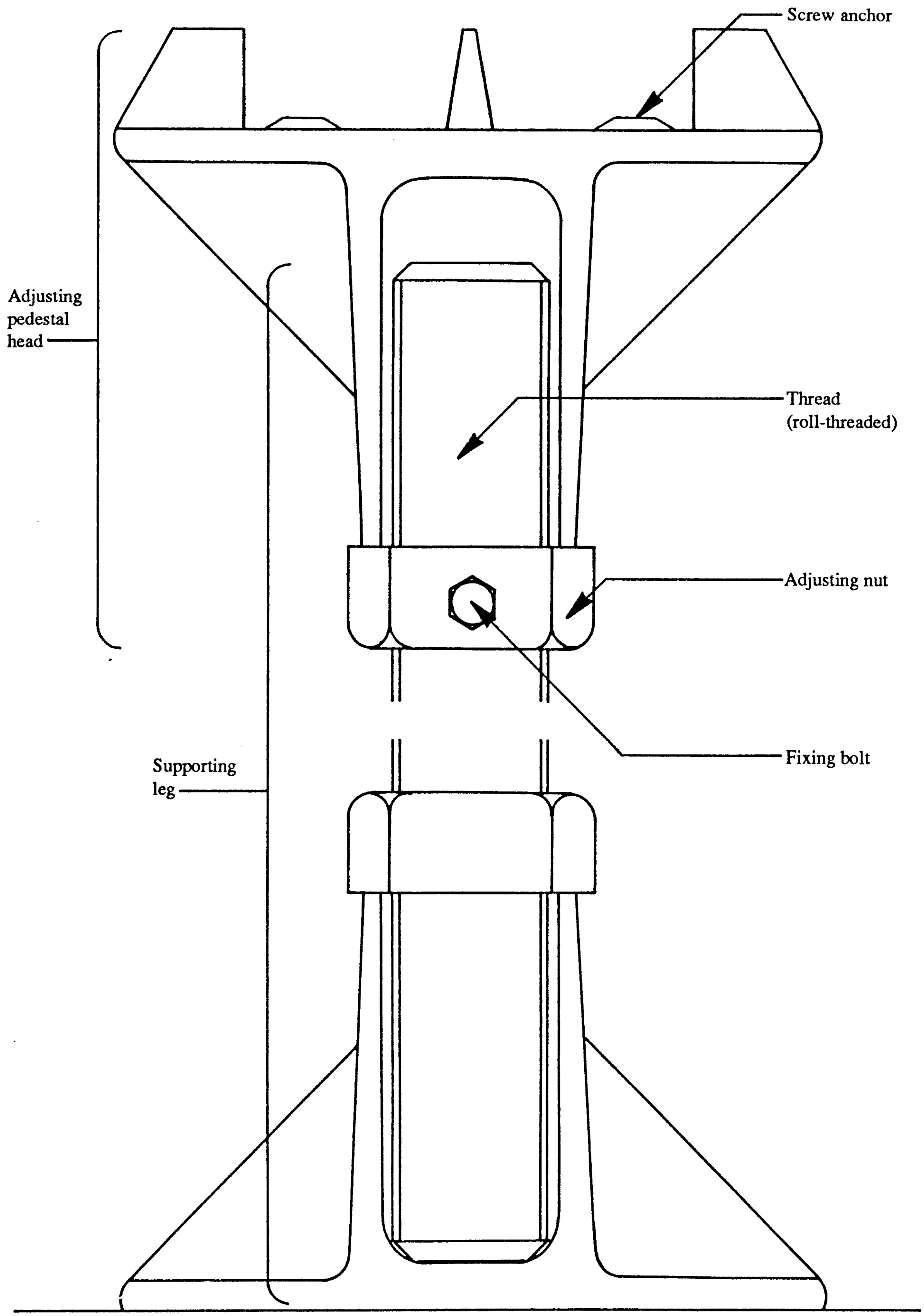


Figure 15:- Pedestal with base anchor.
- for prefabricated or in-situ concrete slabs.

Supreme Model: -

This model is designed with some appropriate dimensions by using standardized elements. Standardization is achieved by laying joists at approximately 8'-0" or 12'-0" on centers; however, non-standardized elements can combine with this method to integrate with a variety of architectural floor plans, i.e. non-standardized floor panels or pressure impregnated, fire-retardant treated plywood on metal decks can be used for the perimeter of the floor plan . The standardized floor panels and non-standardized elements are designed on the same level to avoid the use of stairs and ramps. The actual spacing depends on the design life and dead load, stiffness of the joists and reinforced concrete slabs with or without metal decks. Joist spacing should be designed in four feet increments as the dimension of the accessible floor panels is four-foot square, i.e. 8'-0", 12'-0" or 16'-0"; however, a two-foot square panel can be used with this method with a higher floor load and a more critical deflection criteria.

Modified open-web steel joists or modified castellate steel beams are used for the floor trusses. (Figure 9a-9g). Modified solid I-beams, similar to modified open-web beams, can be used for low-rised buildings such as clean rooms without height restrictions (using solid I-beam in Figure 9f). Shear metal plates (i.e. 8"x8"x1/2" or 8"x12"x1/2") are fillet-welded as composite webs of the upper truss at approximately 4'-0" on centers. This modified steel joist, similar to steel beam, is essentially a truss welded on another truss. The lower truss with or without minor modification is similar to any existing truss. This is referred to as a *Composite Web Joist,* with composite action designed to take place in the web of the upper truss.If the designed floor load is high, hybrid members could be used with high and low strength steel , i.e. A36 steel for the upper two chords and A514 steel for the bottom chord without significantly increasing the depth of the joist.

Composite web joists or beams should be fabricated with cambers according to the manufacturer's specifications. All the joists should be lifted in the upright position during unloading and erection. Steel joists should be erected plumb, and at the proper spacing with a minimum bearing of 2 1/2" on steel and 4" on masonry. *Composite web joists* should be welded to supporting members before any decking is placed with a minimum of 1 1/2"-3/16" weld on each side of the bearing seat. *Composite steel beams* can be bolted or welded to end supports, depending on the types of connection. The end supports could be steel girders, latticed girders, vierendeel girders, castellated beams or masonry walls. With the proper erection and placement of the joists, optional floor anchors could be pre-installed in the shop by welding on the upper chord for the placment of accessible floor tiles later on. With the misalignment of steel joists due to poor workmanship, each screw for the corners of floor tiles is allowed to adjusted within a circular shaft, i.e. a shaft designed with a diameter slightly wider than the shank of the screw. And also, a floor panel is designed with an expansion joint around its edges, for any unexpected misalignment during the erection of steel joists or beams.

The spanning of open-web steel joists or beams should be optimized to allow the installation of piping through the web system. Generally, an increase in bay size with high strength steel joists or beams would be an improvement in joist or beam fabrication, and the cost would remain reasonable. An efficient design and erection of primary framing means fewer columns and beams with flexibility in floor plan layout and unrestricted room arrangements.

Corrugated metal decks, with or without furnished cold-drawn wires, run perpendicular to steel joists supported at least 8" below the upper-top chord by the upper-lower chord without temporary shoring. Metal decks should be formed from cold rolled steel and field-welded with 3/8" welding washers at each deck lap, and one weld in between with a maximum of 24"on centers. The deck segments should be welded upon placement. No bridging and scaffolding are required. Lightweight concrete with optional synthetic fibermesh is poured on the metal decks as a rough finished layer (Figure 10). The profiled steel decking acts as a bottom reinforcement and formwork of the composite concrete slab. Since metal decking is designed to reach from beam to beam, the end of the ribs must be flattened or some preformed filler (say polystyrene) inserted to avoid leakage of the concrete filling. Concrete should not be deposited in large bucket loads in concentrated areas. Pours should be broken off perpendicular to the joist wherever possible. For any thin concrete slab without reinforcement, cementitious or any approved fireproofing should be sprayed on the bottom of the metal decks and steel joists. This composite floor with steel decking will work as a conventional system with a permanent fire barrier, a wind bracing for horizontal load and a temporary working surface for workers.

Floor anchors with pedestals and base plates should be placed on a metal deck before the concrete is poured (Figure 11). They should be aligned with the optional anchors without pedestals (Figure 12) or pre-drilled holes on steel joists to form a two-foot or four-foot grid pattern.They are either welded or adhered to sub-floor with epoxy adhesive. Height adjustment should not be necessary in a field with no significant level change on either the joists or metal decks; even so, the pedestals placed on metal decks are designed with threaded shafts and adjusting nuts to allow for minor height adjustment. For area with concentrated load, deeper trapezoidal decking or cellular steel decking can be used without significantly reducing the space below the accessible floor tiles. A small filler I-beam is designed to span between castellated beams just below the area for floor pedestals to carry an extra load on the composite concrete deck (Figure 13). A small open-web truss-tee subpurlin (i.e. Keydeck truss tees) can also be used on the metal deck for carrying extra load on the pedestals before the concrete is poured. The truss is welded on the shear plates of the upper chords and laid perpendicular to the floor joists for an area designed with pedestals (Figure 14).

An alternative way is to use composite beams with precast, prestressed concrete slabs or panels. The components should be manufactured in readily transportable sizes with site joints both parallel with and peripendicular to the floor beams. Longitudinal joints are arranged along the axis of the beam, and the edges of the slabs so that shear forces can be transmitted. The precast concrete slab behaves as a continuous one-way reinforced slab. Precast concrete slabs are supported 8" below the upper chord as in the case of composite floors with steel decking. The transverse reinforcement bars project from the slabs on both sides. Reinforcement bars or stirrup bars are designed to be reinforced with the shear plates on the upper chords. Transverse joints are arranged perpendicular to the beam. These joints should have sloping sides to hinder the flow of in-situ concrete through the gap. The in-situ concrete must be able to pass on the compressive forces in the concrete flange of the composite beam. Care must be taken in the placment of the concrete slab to ensure enough bearing surfaces on both sides of the support, and concrete slabs should be placed centered on the supporting girders. This method of construction provides rapid erection, as the concrete slabs are laid directly on the beams and no scaffolding is required. Composite action between the concrete slabs and the steel beams is delayed until the jointing material has matured. Careful planning is required in laying floor beams and in producing slabs with very close tolerances and ensuring accurate coordination of the spacings and transport movements.

Lifting and placement of the concrete panels require proper planning. Selection of pick points and the placing of the lifting inserts are very important step to consider well in advance of the construction. Pick points must be placed to properly balance the panel during lifting and to distribute the load on each insert to prevent the concrete strength from being exceeded. All the lifting inserts should be wired or securely attached to the mat of reinforcing steel to prevent dislodgement during the placing of concrete. With the newer connect/disconcect systems, it is important to be sure that all the insert holes are unplugged and free of debris. Since the crane time is very expensive, the less the delay, the more efficient the crane and the speed of erection. If the crane can stay in one place and lift three or four panels, it is much better than moving around for each panel. Change in the rigging configuration should be avoided by using standardized panels or adding more inserts to keep the rigging consistent with larger and heavier panels. Finally, all slings should be connected to the panel at a minimum of two points and run through a pulley or pulleys to balance stress. The panels should be slightly tilted before their final placement on the lowest chords of the upper trusses, by lifting the center of gravity of the unit not directly under the hook.

One of the possible setback with composite precast concrete slabs is the control of cracks on the jointing materials. Another solution is to use the temporary plywood formworks and pour-in-place concrete as permanent slabs. The formworks are supported by roll bars which are locked into the notches in the trusses or beams. A concrete slab is reinforced with welded wire mesh. In the composite stage the top chord is embedded in the concrete and function as a continuous shear connector.

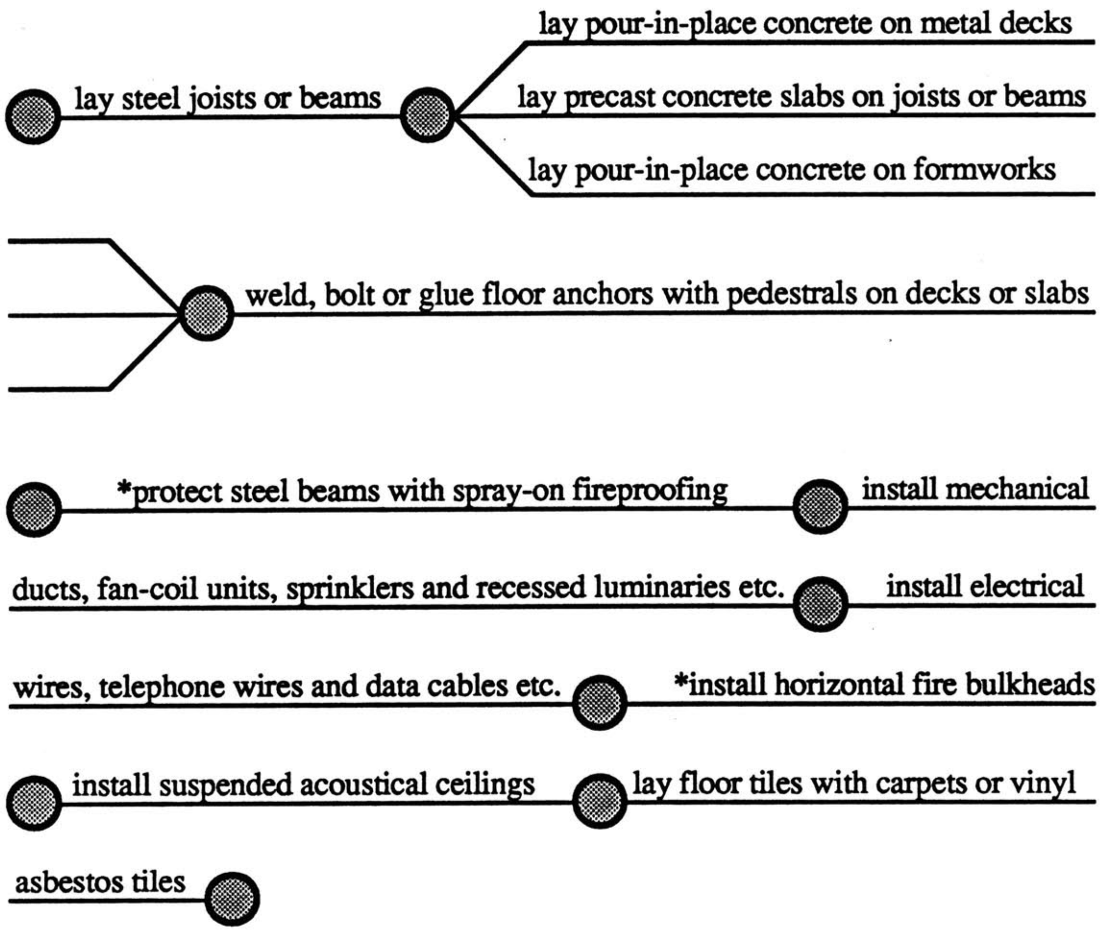
Floor anchors with pedestals are installed on the concrete planks or slabs as in the previous case. They are either bolted or fixed to the sub-floor with an epoxy adhesive. Pedestals are designed with their own built-in leveling devices (Figure 15). They should be aligned with the optional anchors without pedestals or pre-drilled holes on steel joists to form a two-foot or a four-foot grid pattern.

As the composite concrete planks and steel joists or beams are secured, two-foot or four-foot removable floor panels can be fastened to the floor anchors with bolts at their corners, as long as the wiring layout in the plenum is ready for connection to their sunken outlets in the floor panels. A floor panel should be designed for dynamic loads from moving carts, construction robots or automated guided vehicles etc. Circular die-cast aluminium outlets could be used for electrical and communications outlets. The outlets are positioned in the center of the two-foot panel, or in the center of one-quarter of the four-foot panel so that by simply turning the panel they can be placed anywhere on a two-foot grid. A plastic gasket in the edge stop of the floor panels, as in the *Economical Model*, could achieve the tolerances required acoustically. Moreover, perforated panels or floor grilles with gaskets are used with the sub-flooring as a plenum for air return, or a pressurized plenum for air supply. Perforated panels and floor grilles can be supplied with adjustable dampers or underfloor fans if required. Electronic and communication cables, with adequate fire resistance and low smoke producing characteristics, can be installed without raceway when the floor is not used as an open plenum for HVAC. All power supplies should be enclosed in hard-wire or flexible conduits. As in the *Economical Model*, vinyl asbestos tile or carpet can be used as floor finish. Aluminium laminated panel with a lightweight concrete core or an aluminium honeycomb core is suggested for the floor panel with a minimum of 45 pounds per four-foot panel.

As in the *Economical Model*, a horizontal fire separation such as an noncombustible bulkhead should be installed in computer rooms, telephone exchanges and plenums with more than 10,000 sq. ft. in areas depending on the local fire code. A horizontal fire separation can be used to protect expensive computer or mechanical equipment within the same floor.

An acoustical ceiling is designed to be suspended from the bottom chords of the beams or joists. The false ceiling accommodates recessed fluorescent luminaires with electrical conduits, sprinklers, fire detectors, mechanical ducts, air supplies and speakers etc.. This acoustical ceiling could be fire-rated depending on the occupant load and type of construction. Mechanical ducts are designed and located below the slabs by penetrating the open web joists or beams with appropriate spanning. Fresh air could be supplied from the ceiling diffusers, with outlets that discharge air horizontally to handle relatively large quantities of air at large temperature differentials. With low operating static pressure across the ceiling, using return air lighting fixtures can increase operating efficiency of the HVAC system, improve the lighting output and extend the life of the lamps. Slotted tees or grilles can be used with return air fixtures to obtain the specified pressure drop.

Supreme Model (typical construction sequence) *optional sequence



Limitations:-

*The *Supreme Model* costs more than the conventional types of construction with extra money spent on the steel fabrication of *composite web beams* and accessible floor panels; nevertheless, this method costs less than raised floor with a lower floor-to-floor height and a lower consumption of more expensive building materials. The rough concrete slab finished floors, with a faster construction cycle, will create additional savings. *Composite web joists or* *beams* are only economical if they are mass-produced in large numbers. With a stronger and lighter composite deck, less joists are being used with wider spacing than in the case of the *Economical Model* and less money will be spent on the steel fabrication as the total cost is lowered.

Advantages:-

*The *Supreme Model* has the design capacity for carrying more floor load (200-350 lbs./sq. ft.) with air return or supply through the perforated floor tiles for a clean environment.

*A permanent fire and security separation between floors by using a composite concrete slab.

*Total depth of steel joists is reduced by the composite action between concrete and steel.

*No bridging and scaffolding are required during the erection of steel joists or beams and the placing of precast concrete planks or lightweight concrete on metal decks.

*Power supplies are enclosed in hard-wire or flexible conduits, but electronics and communications can be installed without raceway when the floor is not used as an open plenum for HVAC.

Chapter 5 Criteria for Framing Design and Acoustical Treatment

"Planar diaphragmatic action can be achieved by placing trussing in all edge bays of the floor framing to take the highest shear in the horizontal structure."

Modern multi-story buildings by comparison are of much lighter construction and required to be of longer span for flexibility in space planning. Structural systems are influenced by the choice of material, but in all cases they are a combination of slabs, joists and girders. Interior lightweight partitions are not designed for carrying laterial loads, since they are heavily serviced and are liable to alternation in layout and use.

Horizontal framing systems such as floor structures are responsible for a high percentage of the cost of multi-story buildings. Several properties must be considered and incorporated with the framing systems: -

1/ Provision for lighter floor framing systems - a reduction in the weight of the floor permits a reduction in the size of the supporting structure such as columns and foundation. It also permits the use of larger spans and bay sizes.

2/ Adaptability for the accommodation of light fixtures, ducts, piping and other mechanical services.

3/ Provision for space that may be used for moving conditioned air.

4/ Flexibility in electrical and communication services.

5/ Provision for a fire protective barrier - a floor has to prevent the spread of fire by protecting the story above from flame and hot gaseous products. Deformation must be kept within limits and collapse must not occur until a reasonable time has elapsed.

6/ Provision for temporary or permanent horizontal fire separation with noncombustible bulkheads for computer rooms, telephone exchanges or for areas with more than 10,000 sq. ft. to protect expensive computer and mechanical equipment.

7/ Acoustical separation and noise control - a floor must act as a barrier to the propagation of air-borne noise (shouting, bell ringing, speech, radio, etc.) and damping of structure-borne noises (footsteps, impact, scraping, etc.).

8/ Contribution to the reduction of thermal differential between floors.

9/ Suitability for continuous construction regardless of the weather - use prefabricated and semi-prefabricated materials to speed up the erection process in whatever climatic condition.

10/ Provision for suitable floor loading capacity during and after the erection process - a floor must be able to carry, beside itself, fixed loads, such as interior partitions, electrical and mechanical pipework and the varying loads applied before and during occuption.

11/ Elimination of the extensive temporary shoring procedures.

12/ Provision for a top fixing medium for partitioning.

Sunken floor systems are designed to meet most of the above criteria. They are designed to cater to the increasingly complex mechanical and electrical systems, not only in terms of controlling the environment of the building, but also in response to the communications revolution, particularly in the computer age. It is clear that the demands on false floors or large voids for services will increase in the future. With the development of fiber optic cables for installation in buildings, the sizes of cables are decreased and a minimun of 4 inches of clear space below the floor tiles is suggested for the service plenum. The proposed system must permit the highest degree of flexibility in the arrangement of partitions and allow for the installation and support of the various services, all within the minimum thickness.

A conventional floor slabs for multi-story buildings usually has sufficient capacity for diaphragmatic action in the lateral bracing system. The *Economical Model*, with bar joists or open-web steel beams laying perpendicular to floor tiles, do not have enough capacity for the horizontal diaphragmatic action. For such floors with accessible floor tiles and without permanent floor slabs, it is suggested to use a trussed frame or cross-bracing for the horizontal part of the lateral bracing system. With vertical trussed frames, in a three- dimensional trussed framework, the horizontal trussed frame or cross-bracing may be partly trussed rather than fully trussed. Planar diaphragmatic action can be achieved by placing trussing in all edge bays of the floor framing to take the highest shear in the horizontal structure, allowing the accessible floor tiles to be designed for a lower shear stress. Trussing may also be installed along the periphery of the building spanning between the cross girders. Horizontal bracing is usually installed to increase the torsional resistance of the spandrel beams, or when facade columns are not laterally supported by floor beams (e.g., in tubular systems). It is likely to combine the proposed floor framing with any high-rise system required horizontal bracing for efficiency. A "hat truss" on the top floor will reduce drift more than a "belt truss" on the intermediate floor, and can also be used in the proposed floor framing to resist lateral loads. As mentioned earlier in chapter 3, the vertical bracing system can be shear panels, moment-resistant connections between the members, or trussing. Moment-resistant connection is referred to as bracket type bracing, It is used in tall buildings, and also used in lower buildings where it is desired to take advantage of smaller beam sizes and depths and shallower floor construction.

With lighter framing systems, high strength floor beams and longer spans currently planned for *Sunken Floor Systems*, vibration and deflection of the proposed structures begin to control design. Again, careful planning as mentioned earlier must be under taken when steel beams support large open floor areas free of partition or other damping sources.

Special decorative ceilings in foyer, elevator lobbies, and other specialized areas can be used with or without fire rating. The ceiling may be fully luminous or integrated with individual recessed or surface mounted lighting fixtures. As mentioned earlier, solid ceilings with gypsum board or fibrous plaster are mainly used in special areas such as rest rooms and storage areas. Fire protective spaces and security rooms are invariably finished with a solid ceiling.

Acoustic absorption of sound is critical in open planning areas in order to provide the necessary privacy of conversation in working areas and at individual desks. Solid ceilings have better sound transmission qualities, but are less absorptive than tiling. Hard reflective surfaces and soft surfaced materials for absorption can be utilized for sound control. Solid ceilings of the correct form and angle are used as a medium to reflect sound in special areas. Care must be taken to prevent reverberation in spaces with poor acoustical treatment.

Acoustical or sound barrier ceiling is installed above and below plant or machine rooms to prevent noise transmission to adjacent floors. This type of ceiling requires an isolated suspension system and a dense ceiling material to prevent penetration of sound or vibration noises. Ceiling material using multiple layers of gypsum board with lapped joints or woodtex board are suitable for such installations.

The proposed concealed ceiling grid work is suspended from the floor above by resilient rubber or spring mountings. The service piping and ducting should also be suspended on resilient isolators or floor mounted resilient supports (e.g., rubber, neoprene, steel springs, or glass-fiber lined metal clamps). The junction of the ceiling barrier, the external walls of the building, the internal core walls and the columns must have isolated joints with foam rubber jointing strips. All penetration openings through the building structure should be oversized and the pipe perimeter packed with mineral wool and caulked airtight.

As mentioned earlier in Chapter 3 & 4, optional floor anchors on steel joists sandwich 3/16" neoprene pads which work as dampers and acoustical isolators with floor tiles bolted to the 1/4" base plate. This neoprene pad is designed to be replaced if it is worn out due to aging. The hexagonal head screw can be removed with a heavy-duty electrical screwdriver. In the *Economical Model*, floor tiles are designed to sit on continuous compressible gaskets. This airtight and watertight gasket can function as an additional acoustical isolator.

Using fire-resistant ceramic fiber blankets as plenum sound barriers significantly reduces the transmission of sound through suspended ceilings and over partitions. Ceramic fiber blankets are semi-rigid, spun-mineral fiber insulation mats. As in the conventional construction, they can be laid in one layer over the entire ceiling, or in a double layer for only 4 ft. along each side of a partition. Moreover, as a plenum barrier over the partition they can be formed as a vertical barrier, an inverted "T" or a tent barrier. The plenum sound barriers will offer acoustical efficiency and economy for the *Sunken Floor Systems*.

Finally, the accessible floor tiles in the *Economical Model* are modified from existing products for the raised floor systems. They should be partially designed as the conventional floor slabs, to provide functions such as acoustical isolation and diaphragmatic action. On the contrary, the accessible floor tiles in the *Supreme Model* can be available from existing products for the raised floor systems. A costly permanent floor slab is designed as the floor-to-floor acoustical separation and horizontal shear panel. With the industrialized methods, the floor tiles in both systems are mass-produced and prefabricated to lower the production costs.

Chapter 6 *A Glance at the Mechanical Systems for Buildings with Accessible Floor Tiles.*

"A flexible system such as accessible floor and ceiling tiles should be used in the Sunken Floor Systems, for future integration with newer mechanical equipment and outlets."

The popular air conditioning systems currently used in existing buildings are variable volume, dual-duct, four-pipe fan coil and reversible heat pump units. An air distribution unit is installed either within a false ceiling or via swirling floor outlets which is mainly dependant on the importance of the occupant load and desk orientation. The advantages of low level air supply from floor-mounted or desk-mounted air terminals has to be tested and examined under different circumstances, especially in an office with flexible circulation and layout.

Clean air is usually supplied to air outlets at velocities much greater than those acceptable in the occupied zone. Also, clean air temperature may be above, below, or equal to the air temperature in the occupied zone. Therefore, proper air diffusion calls for entrainment of room air by the primary airstream outside of the zone of occupancy. This is intended to reduce air motion and temperature difference to acceptable limits before the air enters the occupied zone; and counteraction of the natural convection and radiation effects within the room. [2]

According to their location in the room, types of supply air outlets are classified as sidewall, ceiling and baseboard or floor outlets. Outlets can be classified into five groups:-

1/ Outlets mounted in or near the ceiling that discharge air horizontally.

2/ Outlets mounted in or near the floor that discharge air vertically in a nonspreading jet.

3/ Outlets mounted in or near the floor that discharge air in a vertical spreading jet.

4/ Outlets mounted in or near the floor that discharge air horizontally.

5/ Outlets mounted in or near the ceiling that discharge air vertically.

1/ Outlets mounted in or near the ceiling include high sidewall grille, sidewall diffusers, ceiling diffusers, linear ceiling diffusers and similar outlets. With cool air discharged horizontally, the total jet movement is counteracted by the rising natural convection currents on the heated wall and drops before reaching the wall. The total air reaches the inside wall and descends for some distance along it. The warmest air in the room is mixed immediately with the cool primary air far above the occupied zone; therefore, these types of outlet are capable of handling relative large quantities of air at large temperature differentials. They are usually selected for their cooling characteristics. There is hardly a stagnant region with minimum temperature variation. However, the warm air tends to rise during heating as a result of natural convection, occuping the region near the ceiling. This result in a large stagnant region and temperature gradient between the floor and some distance above it. Additional heating should be supplied at the base of perimeter windows to prevent drafts at floor level. These outlets should not be used with temperature differentials exceeding 25°F during heating, or in buildings located in northern latitudes where winter heating is a major problem for interior spaces.

2/ Outlets mounted in or near the floor include floor registers, baseboard units, low sidewall units, linear-type grilles in the floor or windowsill and similar outlets. If the primary air is discharged in a single vertical jet from the floor outlet, no deflecting vane is required in the outlet. When the conditioned air strikes the ceiling, it fan out in all directions from the point of contact. The outlets should be installed some distance from the wall, or the supply air should be deflected at an appropriate angle away from the wall. During cooling, the total airflow follows the ceiling for some distance before dropping toward the occupied zone. A stagnant zone forms outside the total air region above its terminal point. The spacing of outlets has to be determined by the air velocity and the acceptable distance of terminal point from the outlets. The common design value has been chosen a distance of 15 to 20 ft. between the drop region and the exposed wall. The air is satisfactorily cooled in the space below the terminal point of the total air. During heating, the total airflow follows the ceiling across the room, and then descends part of the way down the exterior wall. A comparison of Group 1 and Group 2 for heating shows that the stagnant region is smaller for Group 2 than Group 1 outlets, because the air drew in the immediate vicinity of the outlet is taken mainly from the stagnant region, and is the coolest air in the room. This results in great temperature equalization and less buoyancy in the total air than would occur with Group 1 outlets.

3/ This group of outlets includes floor diffusers, sidewall diffusers, linear-type diffusers and other outlets installed in the floor or windowsill. They are characteristized by their wide spreading jets and diffusing action. During cooling, the diffusion action of the outlets makes it more difficult to project the cool air. On the contrary, this is beneficial during heating to provide a greater area for induction of room air. The stagnant region formed is larger during cooling and smaller during heating. These outlets are recommended for heating even with serious demand in heat load.

4/ This group includes floor registers, baseboard units, low sidewall units and similar outlets as in Group 2 & 3. These outlets discharge air horizontally across the floor. During cooling, the total air remains near the floor and a large stagnant zone forms in the entire upper region of the room. Therefore, they are not recommended for cooling application. The total air rises during heating toward the ceiling because of the buoyant effect of warm air. Except the total air region, the temperature variations are uniform across the room.

5/ This group includes ceiling diffusers, linear-type grilles, sidewall diffusers and grilles, and similar outlets, designed for vertical downward air projection. During cooling, the total air projects to and follows the floor, producing a stagnant region near the ceiling. During heating, the total airflow reaches the floor and folds back toward the ceiling. A stagnant zone will result if projected air does not reaches the floor. However, a laminar flow can be achieved by removing air through the the perforated floor tiles as in a clean room. These outlets are used for either cooling or heating and seldom used for both.

For an ideal HVAC system operating under cooling mode with optimum performance in return air, the generated heat should be removed before it is distributed throughout the conditioned space. However, this is difficult for much of the heat released in a space by convection and radiation such as desktop computers, lighting fixtures and occupants. It is a common practice to use ceiling mounted lighting fixtures for air return. With this type of application, a large portion of heat generated by the fixtures is not distributed into the conditioned space. Using lighting fixtures for air return can increase operating efficiency of the HVAC system, improve the lighting output and extend the life of the lamps. In areas that are expected to operate under the cooling mode most of the time, the warmest air in the space should be returned from as high a point as possible to take advantage of thermal stratification. A low static pressure should be maintained across a suspended ceiling to prevent return air forced through the edges of the ceiling panels. This type of ceiling is highly recommended in the Sunken Floor Systems for air returned through the ceiling plenums.

With the rapid spread of electronic equipment, tremendous heat gains are experienced in office buildings. A conflict is developing between the need to reduce energy consumption, and the drive to pour new quantities of energy into highly productive workstations. Without corresponding gains in the efficiency of air conditioning systems, the building energy consumption will be increased to handle the increasing heat load. Up to now, energy conservation has been mainly focused on reducing the load on the air conditioning system, rather than increasing the efficiency of the system in handling its load. It is recommended to use lighting fixtures for air return in the suspended ceiling of an electronic office. Moreover, energy conservation can be achieved by reducting the solar heat gain and lighting levels. Superconductors in computers will also be used to eliminate the heat gain.

It is also highly recommended to use the Group 1 outlets in an office, which are mounted in or near the ceiling of the *Sunken Floor Systems*. Conditioned air is discharged horizontally for cooling to remove heat generated from terminals and other electronic equipment. As mentioned earlier in this chapter, these outlets are particularly suited for cooling, and can be used with high airflow rates and large temperature differentials. They are selected mainly for their cooling characteristic.

The trend is certainly toward one-man, one-workstation offices in the near future which has a major impact on energy consumption and costs; space required for mechanical equipment; distribution ductwork; plenum space between floors; human comfort and productivity. Heat gain from the office equipment has been a small percentage in the past - around 5% or 1.7 Btu/ft^2/hr. The number used for building heat gain from electronic equipment in the near future is 29% or 13 Btu/ft^2/hr. This assume one computer terminal of a currently standard type per work station of around 100 ft^2. In the forseeable future, heat gain from office equipment will increase eightfold, this represents a jump from 5% to 29% of the total heat gain in a typical office building designed to pre-1970 standards. This jump would further increase from 8% to 40% of the total heat gain with current energy-conscious building design. By the year of 2000, the total building heat load may be up to 55%. This implies more area is required for air conditioning equipment, distribution ductworks and plenum space between floors.[3] With the developments in design and fabrication of structural steel for shallow floor systems, mechanical ductworks should be designed to integrated with structural elements such as open-web steel joists in the proposed systems, and adequate amount of area allowed for the placement of mechanical ductworks for efficient air conditioning. The aim of this thesis is to propose such an integration between structure and mechanical, by reducing the overall floor-to-floor height to save tremendous amount of building materials.

Energy costs have climbed so high that total energy operating costs over the life of a building now equal the building's initial capital costs. Building owners, designers and users are finding new ways to lower these costs. As the use of electronic equipment increases, the annual energy costs will continue to rise, independent of international or inflationary pressures. The required energy to power equipment and to remove heat generated by the equipment are the two components to the rise in energy expenditure. The first component is unavoidable, and the second component can be reduced by increasing the overall efficiency of building systems in handling the heat load. The energy cost of removing heat from the new equipment is two or three times the cost of powering the equipment.

There are two methods to increase the overall efficiency of building systems in handling the heat load. The first method will aim at thermodynamic design techniques and incorporate all cost-effective energy sources to reduce life cycle costs. An example of thermodynamic design is high-temperature cooling and low-temperature heating, in which the temperature level of a cooling or heating medium should be as close as the final conditioned temperature. Purchased energy is reduced when chilled water can preform a given cooling task at a higher temperature, and nonrefrigerated cooling tower water can be used for cooling. The second method is desiccant absorption. Desiccant absorption dries the air (dried to approx. 31 grains/lb) to minimize quantity of outside air required for ventilation by taking care of the internal humidity load. It is also used to reduce primary-air distribution, ductwork size and fan horsepower proportionately for shallow floor systems. Desiccant dehumidification also permitted an approximately 30% reduction in the size of the refrigeration equipment, and a 20% reduction in utility energy to handle the heat gain from electronic hardwares.

A flexible system such as accessible floor and ceiling tiles should be used in the *Sunken Floor Systems,* for future integration with newer mechanical equipment and outlets. Relocation and replacement of new ductwork should also be allowed in the proposed system. The capacity and size of the systems such as machinery and distribution ductwork should be proportionately increased with the heavier load in air conditioning. Allocation of extra space should be allowed for system expansion.

As mentioned earlier, there will be a powerful demand for new concepts in the overall efficiency of heat removal systems so that less refrigeraton energy and less fan horsepower is required for a given amount of cooling. Moreover, a decentralization of central air conditioning plant will minimize the quantity of air and the size of ductwork for shallow floor system. Cellular steel floor decks in the *Supreme Model* can be used as primary air flows through selected cells. One significant advantage will be a reduction in the floor-ceiling spaces between occupied floors with smaller mechanical ducts. As mentioned earlier, another example of a reduction in the floor-ceiling spaces is to integrate the mechanical ductwork and the floor structure with open-web joists or beams. Integration of mechanical and electrical services plays a significant role in the choice of the proper floor system. Open-web bar joists, open-web girders, latticed girders, vierendeel girders, castellated beams and the proposed *composite web joists or beams* are recommended to allow the piping and wiring passing through the webs with openings (typical for large spans and steel structures). The *composite web joists or beams* can be integrated with floor joists of small depth spanning one-way or beam and slab system with a smaller spacing crossing the main direction of the piping and wiring.

Group 2, 3 and group 4 outlets mounted in or near the floor include floor registers, baseboard units, low sidewall units, free jet outlets, twist outlets, and linear-type grilles in the floor or windowsill etc. These outlets are recommended for additional heating in a cold climate. However, this floor-based approach should be carefully studied for environmental cooling, especially in an electronic office with high heat gain and occupant load. The location of floor outlets should be integrated with the layout of individual workstations. For areas with low ceiling height such as an office, cool air should be discharged in a single vertical jet from the floor outlet. When the conditioned air strikes the ceiling, it fans out in all directions from the point of contact. The common design value chosen a distance between the drop region and the exposed wall is 15 to 20 ft.. If an air supply enters the space at a low velocity and displaces room air with very little mixing, an additional air supply such as the "microclimate" system should be used by blowing air adjacent to each occupant. The temperature gradient between floor and ceiling should not be greater than 10K due to the reduced ceiling height, otherwise the temperature at floor level may be too low or the temperature at head level be too high for standing occupants. The radient heat from the ceiling should be controlled by the exhaust terminals, possibly via air handling luminaires located in the ceiling.

Slot plates, free jet outlets and floor-mounted twist outlets etc. are common types of floor outlet. The apertures in the slot plates can be either rectangular or round. Reduction of jet velocity takes place by means of the diffuser effect. Room air is induced only at the edge of the supply air. Free jet outlets produce round, non-twist type air jets. The cavity provided in the center of the outlet serves to a accommodate the floor covering. Slot plates have the highest induction of room air than any other diffuser. On the other hand, floor-mounted twist outlets produce air jets with a swirl effect. A higher degree of turbulence is brought with a more intensive induction effect of the indoor air. Owning to the large number of small inclined jets with swirl effect, intensive exchange of energy with the ambient air is attained. The reduction in jet velocity and adjustment of the supply air temperature to the temperature of the room air proceed at a faster rate than in the case with slot plates and free jet outlets. Free jet outlets and floor-mounted twist outlets, similar to utility outlets, are positioned in the center of the two-foot panel, or in the center of one-quarter of the four-foot panel so that by simply turning the panel they can be placed anywhere on a two-foot grid. Each panel has either a utility outlet or an air conditioning outlets. Utility outlets, free jet outlets and floor-mounted twist outlets should be designed with a similar diameter for coherence. For heavy-duty industrial conditions, floor-mounted outlets are constructed of gray cast iron. For rooms with wet floors, the outlets are constructed of plastic.

"Microclimate" system with desk-mounted air outlets has been used in an office which are manually adjustable to individual directions. They are either supplied with flexible ducts or from pressurized plenums below. With the *Supreme Model*, plenums below the floor tiles can be utilized as pressure chambers if the voids are made air tight and dust free. Relocation of desks with outlets can be done with very little effort. This type of outlet makes it possible for the occupants to adapt the air velocity and direction for the individual requirements, which has a physiologically positive effect. Only one outlet is suggested for each desk. However, the desk-mounted outlets alone are not able to cover all cooling load requirements in an office. Additional floor-mounted outlets are required for the remaining cooling load. Air can be supplied to the floor void, as a pressurized chamber at a low enough temperature, to provide dehumidification and mixed with room air via underfloor fans. Linear outlets, rounded twist outlets and desk twist outlets are three different types of desk outlets. In the linear outlet, it is installed along the front edge of the desk. An adjustable baffle plate is provided ahead of the outlet exit, so that only the jet direction is subjected to variation. However, its spread is not subjected to any variation with the linear outlets. The different between the round twist outlets and desk twist outlets is that the rounded twist outlet is fitted with adjustable vanes for varying the fan-wise spread of the jet. On the other hand, the desk twist outlet is fitted with a control disc for a variation in the spread of the jet. The direction of the jet is altered by rotating the housing of the round twist and desk twist outlets. The housing of air outlet is installed at the right or left corner of the desk.

With the *Supreme Model*, the accessible floor tiles are also suggested to be used for clean rooms. Clean rooms has been used in manufacturing such as semiconductor industry. In some cases, the expense involved in providing cleanliness or a suitable environmental condition is often overlooked by comparing with million dollars in profits. Group 5 outlets designed for vertical downward air projection are recommended for the clean room design. Laminar flow is achieved by removing air through the perforated floor tiles. This type of flooring requires a lower level of air movement. Since gravitation is aiding in removing of the particles, the velocity of the air can be considerably lower. It also produces the shortest distance from contaminant generation to contaminant removal from the room. Thus it has the lowest contaminant level of all room designs. Another advantage as mentioned earlier lies in the fact that the plenum below the floor tiles will also serve as a utility distribution channel with unlimited flexibility. Clean rooms are classified by the number of particles of certain sizes that are present in a cubic foot of air, i.e. a class 100 clean room has no more than 100 particles of 0.5 microns or larger per cubic foot of air.

To maintain the clean room environment, a tremendous amount of air circulation is required. The fan and coils of the air circulation system for class 100 or better clean rooms provide 95 cfm/sq. ft. and run 24 hours a day. It is not uncommon for a clean room to circulate more than 1 million cfm of air per day. Oversized ductworks and local fan-coil units etc. can be suspended below steel joists or beams of the proposed floor system. However, an efficient cost saving method is to change the humidity and temperature of 10-15 percent of the total air to the extent that they suited the total air flow, and remixed it with the full volume of air. The larger air volume provides the air flow pattern and velocity to control contaminants. The smaller air volume (10-15%) is that actually required to maintain the design temperature and humidity. A separate dedicated air handling unit is used to supply the partial air treatment to the clean room. This method is used when design air volume is greater than the conditioned air volume. The above method could reduce the costly equipment, the size and number of mechanical ducts in the proposed floor system. Another cost saving method is to divide the clean room into modules by splitting them up among individual or group of fans, where each is equipped with its service space for equipment and the air conditioning units. A large quantity of air is circulated locally to maintain the air cleanliness criteria, which allows considerable construction cost saving on air conditioning equipment.

There are two basic ceiling designs for a clean room which could be intergrated with the *Supreme Model.* These designs consist of a packaged system and a built-up system. A packaged system of tunnel modules is essentially a large box with a fan on top and a HEPA filter on the bottom. The advantage of a packaged system is its lower cost. A built-up system has fans located in an area remote from the clean room. The latter system is perferable because it removes fan noise from the adjacent clean room area, allow for larger fans and servicing without interruption of the clean room operation. Duct HEPA filters and a pressurized plenum are two methods of bringing air to the filter in the built-up system. The filters are held in place with a special grid system that can be constructed of either T-bars or a liquid filled channel system. However, the latter system is far more expensive than the previous one.

Additional space, such as an air shaft, basement or interstitial floor, should be provided for redundant mechanical systems in the proposed floor system. These redundant systems are usually required to keep the clean room from being forced to shut down when there are mechanical failures or for periodical maintenance. They can be monitored through air flow switches. Failure of any mechanical equipment can ring an alarm at the computized monitoring facility to operate any standby units. Back-draft dampers prevent reverse air flow through the idle fans which are mounted outside the clean room area over the return air shaft. Exhaust air can be expelled into the atmosphere, or trapped by water and conditioned as acids or treated by special burning and scrubbing methods for highly toxic materials.

As mentioned earlier in chapter 3, mechanical ducts in the *Economical Model* running parallel to floor joists are supported by stringers or cross-bracings; consequently, mechanical ducts running peripendicular to joists are suspended from the steel joists by passing through the open webs with appropriate joist depth and spanning. Spacing of hangers are usually combinations of 4 and 8 ft. which can be based on either the duct "cross-sectional area" or the "half-perimeter" method, depending on the design engineer's specification. Additional cross-bracings can be used for areas required extra duct hangers, i.e. hangers need to be installed at the ends of mains, linear diffuser plenums, ducts attached to flexible connections, etc..Two-zone service runs in two planes by allowing the mechanical ducts suspended above electrical and communication cables with resilient hanging rods or metal straps. In-line suspended fans or unit heaters should be suspended with vibration-isolation hangers. In the *Supreme Model*, mechanical ducts are suspended from the conventional steel or concrete deck with duct hangers. For the most practical purposes, the round, oval, square and rectangular ducts can be used for the *Sunken Floor Systems*. The minimum height to width ratio should be at least 2 to 1 for rectangular ducts with acceptable frictional losses in air movement. Acoustical liners such as fiberglass insulations should be used by wrapping around the ducts for area with high level of mechanical noise.

To sum, mechanical systems designed in the *Sunken Floor Systems* should be flexible enough to handle the demand in air conditioning, especially in an electronic office and in a clean room with shallow floor systems. A conflict is inevitably being developed between the drive to reduce building energy consumption, and the need to pour new quantities of energy into productivity-increasing machines. Another conflict is developing between the drive to reduce floor-to-floor height, and the need to increase air conditioning supply with high energy consumption. The efficiency of air conditioning should be increased with some of the methods mentioned earlier; moreover, a mechanical system should be flexible enough to be replaced or upgraded in the future with a new generation of system. This thesis is written in 1987, the future computers will be "cooler" and "quieter" with the superconductors. Under super-conductivity, elimination of heat caused by electrical resistance will have a profound effect on the design and performance of computers. With the cooperation between architects and engineers, mechanical units in the shallow floor systems should be designed to reduce system load and increase system efficiency, by overcoming any constraint coming in the near future.

Chapter 7 *Fire-Resistant for the Proposed Floor Systems with Steel-Frame Construction.*

"To fulfill the standard of fire protection in multi-story buildings, Sunken Floor Systems are designed to integrate with modern sprinkler systems."

Concern for fire safety in multi-story buildings had come into focus for a long time. Serious fires in multi-story buildings has demonstrated the need for greater emphasis on the fire protection and life safety associated with high-rise buildings. Many multi-story buildings usually lack viable exterior access to the upper floors for fire fighting. In addition, it is often hard to quickly locate fires in multi-story or high-rise buildings as smoke may have spread several stories beyond the origin. The fire protection systems within the multi-story buildings must be reliable for fire detection, fire suppression, escape and refuge to ensure life safety and reduce damage to the contents and structure of buildings.

At cold climate locations, multi-story buildings also have the potential for significant "stack or chimney effect" due to the inside-outside temperature difference. During a fire, smoke can easily move to the upper floors through vertical shafts and stairwells. Where wind velocities are considerably greater at upper levels, suction on "down-wind" side can cause increased pressure difference between upper and lower levels.The migration of smoke and toxic combustion products throughout a high-rise building due to stack effect presents a greater hazard to life, and more serious hindrance to fire-fighting efforts than the spread of the fire itself. Mechanical pressurization, fire-rated dampers, vent shafts and smoke ventings are effective in controlling the stack effect in the proposed systems. To confine smoke movment in the fire area, the fan supplying air to the zone or floor involved in the fire is turned off. The return air system from this zone is also shut down and the smoke is exhausted to the outdoors. The mechanical system serving the surrounding zones establishes an increased or positive air pressure above or below the fire zone by closing return and exhaust air dampers and keeping supply air dampers open. In addition, mechanical air distribution networks can be divided into zones by floors or subdivided floors to confine fire. Fire-rated dampers are used to restrict heat flow through air duct, also may prevent the spread of smoke if there is sufficient pressure difference on opposite sides of the dampers. A damper consists of a single blade or of connected multiple blades. Each damper is constructed with 22 gauge galvanized steel protected on both surfaces with ceramic blankets. It can be operated directly by a heat-sensitive device such as a fusible link or remotely by a fire detection device. A damper with thermal blanket skirt operated by replaceable fusible link is also recommended. A ceramic insulating blanket can be used together with a diffuser pan, to give additional fire protection. Vent shafts and smoke ventings provide a means of heat release from buildings, remove smoke and gases, and help fire fighters locate the fire. Heat venting can also prevent activation of sprinklers in areas remote from the fire. Vent shafts exhaust smoke utilizing the stack effect caused by cold weather conditions; however, these shafts will not exhaust smoke when the inside and outside air temperature are equal. Smoke ventings are usually panel wall vents or roof vents to remove heat and smoke from fires in buildings. As in the conventional buildings, smokeproof enclosures are required for at least one stairwell, or all exit stairwells may be pressurized when the building is sprinklered.

Sprinkler systems have become a standard for fire protection within the U.S. and possibly in all industralized countries. Reduction or elimination of fireproofing around structural members is usually permitted by most building codes with sprinkler systems. An unprotected sprinklered steel building can usually be built for 20 percent to 40 percent less cost than a fire-resistive unsprinklered building. The temperature is immediately brought under control with sprinkler systems, thus permitting the use of less fire-resistive construction and reducing building cost. In U.S., National Fire Protection Association records indicate that automatic sprinkler systems are over 96% effective in suppresssing fires. Moreover, sprinklers open only when there is sufficient high temperature to require water. The fact is that many small fires in sprinklered buildings are extinguished or controlled by three or fewer sprinklers. To fulfill the standard of fire protection in multi-story buildings, *Sunken floor systems* are designed to integrate with modern sprinkler systems. Accessible floor tiles in the *Economical Model* are designed with continuous watertight and airtight gaskets around their edges; therefore, water penetration and possibly smoke infiltration throught the edges of each tile is prevented. As in the conventional systems, sprinkler heads can be activated by soldered links, glass bulbs or electrical devices. They are constructed according to the application requirement, so that they will open at predetermined temperature. Heads are also rated for use at maximum ceiling temperatures to help prevent premature operation from extended exposure where elevated temperature is normal. Standard pendent heads in the *Economical and Supreme Models* are recessed in molded ceilings. Cover plates also can be used to hide pendent heads by matching the color of the ceiling surfaces. The maximum spacings between sprinklers is normally 15 ft.. Sprinklers must not be spaced too close together by delaying activation of adjacent sprinklers. Dry, wet and deluge pipes can be used in the proposed systems. In some newer sprinkler systems, the wet pipes can be used as the chilled-water return pipings of the air conditioning units by reducing total piping costs. Floor openings in the proposed systems (e.g., stairwells, escalators) can be protected by a sprinkler system. Spray nozzles should be oriented to cover openings with water during a fire. Sprinklers have become smaller in size and the water requirements have been significantly lessened, by reducing damages to expensive computer equipment and valuable documents. Optional water sensors, fire protection systems such as water spray equipment or upright sprinkler can be installed within the plenum with potential fire hazard, especially for the open-web bar joists without spray-on fire-proofing.

If water damage would be disastrous, in computer equipment rooms or storage rooms for valuable documents, a water flow-sensitive devices in the sprinkler system piping can be used to activate alarms indicating fire, leakage, or damage. Dry-extinguishing systems such as carbon dioxide or halon for supplementary protection of the building where equipment or documents could be damaged by water. These applications include computer rooms, electronic installations and documents storage rooms etc.. High-pressure cylinders are used to store carbon dioxide and halon concentrations in liquid state. Unfortunately, carbon dioxide won't support human life, making it unacceptable for the application in a building with high occupant load. With pre-engineered systems, halon 1301 will not support combustion at concentrations of five percent in the atmosphere, but unlike carbon dioxide it allows people to breathe.

Standpipes are also proposed to be used in the *Sunken Floor Systems*. With reliable pressure regulating valves and pressure control valves, standpipe systems have permitted to be installed with much higher zone height as before (e.g., 1,400 ft). This eliminates the need for high-level storage and cut down on the total number of pumps required. If a building is designed with sprinkler systems, standpipe systems can be used without any standby hose.

The structural performance of steel is controlled by the change in mechanical properties and the deformation experienced during a fire. The mechanical properties of steel decrease with temperature, it can deform under the effects of expansion, the reduction of tensile strength and yield strength before the element attains its critical temperature. Uniform temperature are attained rapidly in many steel structures with their high thermal conductivity; therefore, a heavy section will heat up more slowly than a light one and perform better in fire. The heavier chords of the deeper members have more mass and present more of a heat sink, which would tend to extend the time before limiting temperature are reached in the steel. Fire protection of steel is determined whether it will reach its critical temperature within the fire resistance period imposed by building codes. Substituting members with high- strength steel have no significant effect on the fire endurance. Structural steel is protected with methods such as cladding the steel with insulating materials, screening with suspended ceilings, water cooling by water sprays and using composite steel with concrete elements.

Fire moves rapidly upward by convection and can spread laterally along ceilings in a confined area, so that smoke and hot gases will rise and eventually fill the entire room. The closer the ceiling is to the burning materials, the more heat it will radiate. The mushrooming hot gases, heated ceiling material and upper wall surfaces of a room radiate energy down to the unignited materials below. Due to the large temperature differental between floor and ceiling in a fire; open-web steel beams, girders and metal decks in *sunken floor systems* can be protected with spray-on fire-protection materials, except for the open-web steel joists spaced 4'-0" on center. Spraying fire-protective materials on open-web steel joists is usually not economical, unless it is done by construction robots with sensors and spray nozzles. Gypsum plaster, perlite plaster, vermiculite plaster, mineral fiber, portland cement concrete or plaster and intumescent coatings are used to protect structural steel members within the plenums.

Fire-rated suspended lay-in panels are used for ceiling construction in the *Economical Model.* These panels consist of densely packed fire-protective materials such as gypsum, perlite, vermiculite, and mineral fibers. Extra fire protection is provided with one or two layers of ceramic fiber blankets above the suspended ceilings. In the *Economical Model,* the steel housing of the recessed light fittings is protected with gypsum boards, compressed rock fiber boards or compressed vermiculite boards. Fixture protection is achieved by cutting fireproofing materials into 3 pieces, trapazoidal in cross-section, with openings at both ends to release heat from a recessed light fitting. As mentioned earlier, fixture protection should provide a minimum of 1/2 in. clearance between the top of the fixture and the enclosure. The enclosure is then covered with ceramic fiber blanket, except at the end of the enclosure. Metal stringers or bridgings, with the continuous solid gaskets in the *Economical Model* are coated with intumescent coatings. These spray-on coatings are mixtures of resins, binders, pigments, ceramics and refractory fillers. A chemical reaction occurs at an elevated temperature, causing the coating to enlarge to many times its applied thickness and forming an insulating blanket. They are primarily used for nonexposed steel subjected to elevated temperature as prolonged exposure to flame can destroy the char coating. A compressible gasket with a woven fiberglass cord, filled with intumescent fiber, is used on the floor tiles. An optional compressible gasket is used for redundancy. These gaskets expands when heated and solidifies when exposed to fire, to prevent fire and heat penetration through the edges of each panel. Lightweight concrete floor tiles reinforced with wire-mesh are highly recommended for fire safety; however, aluminium laminated tile with a lightweight concrete core or an aluminium honeycomb core is also suggested for the floor tile. Floor tile with aluminium honeycomb core should be sandwiched with at a minimun of one layer of fire protective material on its lower surface. The fire protective material could be compressed rock-fiber board or compressed vermiculite board.

Composite web joist or beam provides substantial savings in fire protection where the composite floor slab offers partial protection to the structural members, i.e. the upper half of the truss is protected from a fire below by the permanent floor slab without application of further insulating materials. In addition it will improve scheduling and cut construction time. For floor assemblies, failure occurs when the average temperature on the exposed surface has reached its criticial temperature or when the construction no longer can sustain the applied load under high temperature. With high thermal conductivity of steel, a structural section with partial protection will heat up slower than an unprotected one and perform better in a fire.

As mentioned earlier, permanent or temporary horizontal bulkheads are used for computer room and plenums with more than 10,000 sq. ft. in areas, depending on the local fire regulation. Fiberglass cloth bags, filled with a combination of mineral fiber and incombustible expansion agents, will expand when heated and solidify when exposed to fire. Any protrusion such as cable melts or burns into the seal will become enveloped by the fiberglass cloth bags because of the constant expansion action, thus preventing any continuous deterioration or burning through.

Sunken floor systems are designed to cope with modern fire-protection technique in multi-story buildings. As mentioned earlier, all power cables placed in the plenum must to be installed in hard wire, flexible conduit or in a metal covered wireway. A cable including fiber optic with adequate fire resistant and low smoke producing characteristics can be installed in the plenum, without conduit or metal raceway. This exception includes wire and cable used in remote control, signaling and power limited circuits, fire alarms, communications and CATV and radio distribution circuits. Almost all plenum cables use fluoropolymer jackets, typically either polyvinylidene fluoride homopolymer and copolymer, a copolymer of ethylene and chlorotrifluorethylene, or a copolymer of tetrafluoroethylene and hexafluoro propylene. For competition, many designs also use a fluoropolymer primary insulation, or a flame-retardant polyolefin, or a smoke-supressed PVC.

The area of openings in fire-resistive membrane ceilings is limited by most building codes and regulations, i.e. according to the American Iron and Steel Institute, air duct openings can be spaced so that area of openings does not exceed 576 square inches per each 100 square feet of ceiling area. The individual duct opening is limited to 576 square inches but the maximum linear dimension of the opening is limited to 30 inches. Finally, the floor openings for cable and piping penetration can be permanently or temporary sealed off with mineral wool and ceramic fiber-based caulk or putty, fire-resistive elastomeric sheets with aluminium foil, poke-through fittings and intumescent fire stop etc.. Typically, intumescent materials expand eight to ten times their orginal size when exposed to temperatures around 300 to 350 degrees Fahrenheit, forming a hard char that seals the gap left by melted cables or pipings. Intumescent sealants are available in caulk form, in sheet form for lining penetrations and in removable glassfiber bags for large openings that require frequent accessibility. The underside of poke-through assemblies can be protected by spray-on insulation undercoating, intumescent mastic coating on the conduit, or heat shields. Unprotected, poke-through assemblies can lower the fire resistance of floors to only a few minutes. Where pipe or cable penetrates continuously through three or more floors, it should be enclosed in a shaft. As in the conventional systems, floor openings between curtain walls and floors of the proposed systems should be fire-stopped to prevent the spread of fire, smoke, and gases. Mineral wool or rockwool can be used as fire-stop materials.

Smoke detectors are required to be installed in the plenums of the proposed floor systems to provide early warning signals. They can be attached to the underside of the floor tiles connected with flexible connections to sound an audible and visual alarm. Heat sensitive cables and sensors, manual pull stations, flow valves in sprinkler systems or smoke detectors in spaces and air ducts send in signals to fire alarm systems. Detectors should be well-maintained and be installed in buildings at positions where heat or smoke will collect. They have individual characteristics which should be matched to the anticipated fire hazard (e.g., photoelectric for smoldering fires, ionization for flaming fires, infrared for flash fires). These devices are connected to annunciator panels which are located in control rooms near the entrance or in the lobby of a building. Building compartments or fire zones are indicated on the annunciator panels which are divided into corresponding sections. When an alarm sounds (e.g., bells, buzzers, chimes, horns), a flashing light on the panel indicates the area of the building involved or the location of the device that triggered the alarm. The system in respond can close the fire doors, call the fire department or integrate with other controls to activate a smoke-control program and recall elevators.

To sum, the proposed fire-protective systems or methods in the *Sunken Floor Systems* should be adequate. The actual fire-resistance rating has to be determined by the laboratory testing such as the examinations from Underwriters Laboratories in U.S.. However, it is important that fire-resistance rated constructions be installed in buildings in strict accordance with the design of the test specimen and the procedures used to erect it in the test furnace. Finally, a periodical building inspection should be carry out not only by the local fire department, but also by the building owners, facility managers and janitors to ensure fire integrity of the floors.

Chapter 8 *Telecommunications Services in Intelligent or Smart Buildings*

"There is a growing concern of the proliferation of data cables in modern electronic offices. Many existing offices are unable to handle the rapid increase in communication networks."

The increasing capability and lower cost of computers has led to their popularity in many organisations. Furthermore, the requirement for sharing data has led to the need to transmit data to other users or to a communal data storage device. The owners and designers of new buildings have to face with this change in the form of computer installations and service selections before the buildings are designed. One of the smartest choices is to choice a highly flexible system such as the *Sunken Floor Systems* for any future changes.

In the past, the transmission requirements of telephones and computers were different. Voice traveled as an analog electrical signal, data as a digital signal. In modern communication, such as telephone and television signals, voice is converted from analog to digital, transmitted, and then reconstructed as an anolog signal. The distinction between the signals of voice, data or television is disappearing. Because the universal language of microprocessors is binary code or digital data, the functions of transmission systems employing microprocessors are beginning to overlap. Telephone systems, orginally designed for voice traffic, now carry both voice and data. On the other hand, networks built to link computers have acquired voice capabilities. During the planning of main cable routes for telephone into a building with the proposed systems, consideration should be given to the requirements for routing data cables since the principle of their usages and the installation requirements for both types of cable can be similar. Also, consideration should be given to the electronic equipment and patch panels which may be required for the data wiring system and the space and power requirement for such items. [4]

The wiring type proposed to be used with the *Sunken Floor Systems,* varies from simple multicore cable similar to that used for telephone systems, through sheathed multicores, twisted pairs, coaxial, twin coaxial and catv to fiber optics. Twisted pairs and multicore cable transmit on narrow frequency bands (300 kHz or less). They are inexpensive and known as baseband conductors typically at a frequency of 3kHz and data at speed up to 9,600 bits per second. Coaxial and fiber optic cables have higher transmission rates. They are known as broadband and accomodate signals such as television requiring a wider bandwidth, which typically occupies a band at 4.5 mHz. Fiber optics are becoming increasingly important in the transmission of data. It is recommended to use fiber optics, especially for security in communications with the *Economical Model.* Fiber-optic telecommunication offers advantages in many areas over other transmission mediums, such as:- [5]

*Good security in communications - One of the biggest concern in the *Economical Model* is floor-to-floor data security. While fiber-optic systems can be tapped, it is easier to detect intrusion on fiber-optic networks than on other types of networks. Most tapping techniques depend on the existence of an electromagnetic field generated by an electrical signal. A fiber-optic system requires a physical tap, resulting in an easily detectable signal loss.

*Light weight and small diameter - Weight savings of up to 80 percent can be expected when optical fibers are used for the same transmission capacity as comparable electrical cables. Optical-fiber cables can be combined with power cables when available conduit space is limited. In the proposed systems, a plenum space of approximately 4" is supposed to be deep enough for optical fibers with one-to-one ratio of workers per keyboard device by the year of 1990.

*Wide bandwidth and short wavelength - This wide bandwidth capability allows higher data rates per given length of cable. Because of its short wavelength, light can carry about 1000 times more information than present electrical communications. Optical fibers can meet present and future demands in carrying a tremendous amount of digital information such as voice, data, and pictures at an affordable cost. With a shallow plenum for the proposed systems, new communications hardware can be added to the data highway without the need for much additional wiring.

*Good electrical isolation - Fiber-optic cables never short-circuit, shock, or spark. This eliminates the risk of fire hazards with accessible floor tiles. Fiber-optic cables are dielectric. Since conductive ties do not exist between areas of different potential, ground loops are completely avoided.

*Low attention - Optical fibers offer longer transmission distances, because of the purity of the glass, at high data rates and lower signal attention than coaxial cables. Saving will also be expected because fiber-optic systems can transmit over longer distances without repeaters and need less installed equipment in a plenum or in a closet.

*Free from electromagnetic interference (EMI) and radio frequency interference (RFI). - Fiber-optic cables neither pick up nor emit electromagnetic radiation. There are no false signals, noise, or cross talk which are vital in protecting against data distribution errors in telecommunications and computer systems. This is especially useful in an accessible plenum with numerous cable-routing capacity and layout.

*High physical strength - fiber-optic cables have high strength-to-weight ratios than most metal cables.

Several trends influenced the growing use of accessible floor systems. These include the practice of rearranging workstations, more workstations outfitted with terminals and return-air ducting for air-conditioning. The *Sunken Floor Systems* offer the capacity for an immense amount of wiring through the building floors, and cabling connections are highly flexible for shifting workstations and equipment. Wiring requirements in an accessible floor system has the following characteristic:-

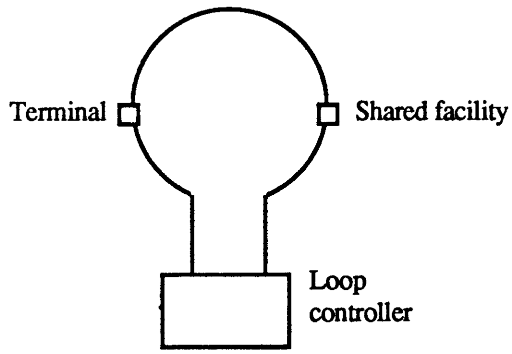
*High capacity - The ability of a cable system to feed entire electronic and communication systems with almost unlimited amount of capacity. Moreover, the plenum space can be used for air conditioning.

*High flexibility - Speed and low cost of adding new cables and outlets or taking out old cables and outlets. The floor below is not disturbed, overhead ladder work is eliminated and labor hours are reduced.

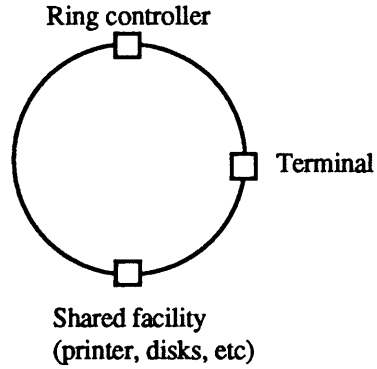
*High initial cost and low life-cycle cost - Accessible sunken floor systems are cheaper than raised floor systems, but their initial cost is still comparatively higher than other systems. However, access floor has more affordable life-cycle-cost, it makes wiring changes so easily that they can be done by janitors or secretaries.

*Good appearance - From an aesthetical point of view, accessible floor systems have the uncluttered appearance in modern electronic offices or workplaces by concealing most of the cables under their floor panels.

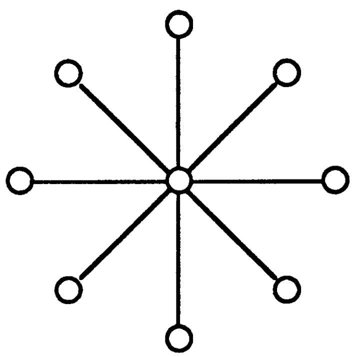
It is important and essential to be familiar with the necessity of wiring requirements within various zones of office space, voids and riser, so as the proliferation of data cables in the future. The saving in transmission costs of a simpler network over the complex network is obvious, plus addition space is allocated for future cables within the shallow plenum. A network can be take the form of a ring, loop, star or bus arrangement:-



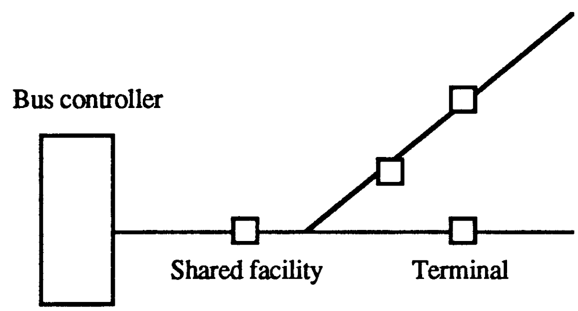
Loop System



Ring System



Star System



Bus System

Star networks are typically consist of a terminal individually wired back to a separate port on the main frame. They are common where the installation has been designed around a central mainframe. As the number of terminals required increased, so do the number of cables all the way from the new terminal to the mainframe. This results in a plenum full of cables terminating in a state of utter confusion. A remote controller, as the central point for a star sub-system, is used to reduce radial cabling by connecting to the central mainframe. [6]

Loop networks consist of a controller which receives messages from one cable connected into it and sends the message out by way of another cable. All terminals and equipment are connected into the loop of cable and all share the controller. This system is used for up to 30 terminals as it tends to be a relatively slow method of passing information.

Ring networks consist of a ring of cable with a terminal node connected into it at each access point. Each node is used for controlling the network and carrying equal status. The node point must be intelligent and programmable in order that the operation system can function on the shared ring.

Bus or highway networks consist of a main cable to which all devices are connected and is a development of the inbuilt system of connecting the internal components of a computer. Each terminal is connected to the cable and is assigned an address so that the shared cable can be used as a communal transmission path. An extension of this system is a tree trunk cable branches off to serve other devices on a submain.

Two terminals on a network are communicated with special technique to ensure that the various messages do not interfere with each other. In the point to point system such as the star network, the interference does not occur as the cables are not shared with each other. The star network operates as a point to point system, but where remote controllers are used a polling system is introduced. This involves the interrogation of each terminal by the central processor on a one by one basis. All the other networks use sharing technique such as multiplexing, carrier sensing and contention techniques, fixed slot and token passing which all usually require some form of additional hardware and software.

The capacity of wiring within a given floor level is dependent upon the accommodation for the wiring with appropiate floor systems. As mentioned earlier in this chapter, accessible floor systems are generally preferable since they tend to give the high degree of flexibility with almost unlimited cabling capacity. The type of data connector to be used should also be considered since this can effect the nature and size of the items such as floor outlet boxes on the floor panels. Such cable routes can often be used for telephone cabling. The requirement for permanent labelling of all cables at short intervals along their length and detailed dimensioned record drawings, indicating cable routes and labelling, are essential for the wire management. The management plan should not only be included in the drawing, but also be incorporated in contracts with equipment vendors. Data and telephone cables are encased in conduits or raceways for air return handling plenums or lie free on the floor for non-environmental applications. Cables also lie free on the floor when plenum cables is used.

As mentioned earlier in chapter 3 & 4, a circular die-cast aluminium outlet could be used for electrical and communication outlets. The outlets are positioned in the center of the two-foot panels. In the four-foot panels, they are positioned in the center of one-quarter of the panels; so that by simply turning the panel they can be placed anywhere on a two-foot grid. The cover of each outlet is designed to accommodate various floor coverings. These outlets are connected with flexible conduits or fire-resistance cables for convenience in the relocation of outlets. Each floor-mounted outlet consists of power supplies, telephones, lighting switches and data supplies. Cables laying free on floor are connected to circular outlets and boxes attached to the undersides of the panels. The boxes on the undersides of the panels should be water-tight, especially in case of the *Economical Model.*

There is increasing evident in our competitive open market that communications technology is the key to success for the modern business trader, and making the wrong decision in a confusing market place can be extremely costly both in time and money. The decision today must be able to design the building services in conjunction with the communications services such as telephones, satellite dishes; as well as computer equipment such as computer terminals, disk drives, modems, printers, plotters, digitizers, VDTs, and other professional electronic gear belonged to the end users. On-line database access provide vast libraries of information to subscribers using communication devices. Many business managers are using on-line sources to access vital business information such as Dow Jones, business and economic news right in front of their computer terminals.

Today, building tenants are calling for a wide range of expert systems and expect these changing services to work for their business in any order on any floor and at any desk. Moreover, the developer or landlord has to offer something more than an empty space, ready to accept a telephone exchange, a flexible outlet and a desktop computer on every floor and at every desk.

In the future, a newer generation of personal workstations will offer a much higher capability with a lower price than ever before. This thesis is written in 1987, a second generation of workstations will offer at least 10 times processor speed, memory size and display capability in approximately every seven years. Future workstation vendors are moving toward standardized networks for the interconnection of a wide variety of computers. Large amount of data or programs are transfered in high transmission rates between machines with fiber optic links. With image compression, successive images will be sent directly between workstations or computers anywhere in the world via satellites.

There is a growing concern of the proliferation of data cables in modern electronic offices. Many existing offices are unable to handle the rapid increase in communication networks. With an affordable construction cost , a newer distribution system such as the *Sunken Floor Systems* should be developed for the intelligent or smart buildings of tomorrow. An unlimited amount of cabling capacity and flexibility should be provided to meet the the most powerful workstations coming into our business life.

Chapter 9 *Strategy in Space Planning with Layout Requirements and Design Options*

"The idea behind the accessible floor tiles is to provide "instant flexibility" for workers without waiting for electricians."

Although electronic equipment is common in a number of today's automated buildings, many employees are still at workstations designed for yesterday's manual environment. With the introduction of flatscreen hardware, fiber optic cables, and telephone digitial networking, personal comfort should be the priority in space planning with the proposed floor systems. Although cost control is an important issue, human comfort can increase worker productivity, i.e. low noise levels, glare-free, good air quality and privacy etc.Diffuse lighting, demountable partitioning system, adjustable furniture and desk-mounted outlets are among the top priorities to fit the individual's needs. The proposed accessible floor tiles has the advantage of its flexibility in the relocation of workstations when designing for user's need. Optional desk-mounted air outlets can be installed at individual's workstations for personal comfort.

As mentioned earlier in chapter 3, a demountable ceiling-to-floor partitioning system is suggested to be used in area requiring acoustical and physical privacy. It should also be used in areas with high noise levels such as phone ringing, conversation, talking on the voice computers, noise from the printer and noise from the news wire machines etc.. Also, different tenants can share the same floor with interior partitions for security and acoustical separation. Modular components are also suggested to be used in the proposed partitioning system. To cope with floor deflection, interior partitions could be hung from the ceilings with pin or slot-plate connectors suspended from the main runners. This supports the partitions at the node points on the 4-ft square grid. The head track can be designed to allow for vertical live-load deflection. Partitions are free to move from side to side in relation to each other with slip joints at the vertical junctions. Doors and their frames are installed on the floor and slide up and down in relation with the partitions. The wall partitions can easily be moved by releasing spring-loaded connections. These apply a vertical force to the floor and ceiling to keep the partitions in place by friction. The base channel of the panel can be jacked up to allow floor tile removal below the panel. The panels can be easily moved manually with a special machine designed on wheels. The partitions stop at suspended ceiling level to prevent the transmission of sound between offices, and they can be lined with gypsum boards and sound attenuation blankets to improve acoustical isolation. All the joints should also be carefully sealed with a mechanism such as compressible vinyl gaskets for sound attenuation. Glass and mullions can be used for areas requiring visual accessibility. Glass is also recommended for areas that are psychologically isolated. The ceiling grid should be designed according to the geometry and location of the floor grid, so that the layout of panels or partitions is lined up with the floor-and-ceiling grid. Interior partitions are layed out perpendicular to the curtain walls or claddings for maximum efficiency.

Low partitions or semi-enclosures are also recommended to be used in areas where acoustical separation and privacy are less important. Their location do not necessary have to follow the layout of the floor tiles, i.e. curvilinear shapes or round corners can be used in their design. They can be constructed as a free-standing boundary between workstations, or an integrated part of a furniture system. Panel construction should be incorporate sound-absorbent fabric that encloses a core of fiberglass or similar material. Hard and transparent surfaces such as nonacoustical and glazed panels are optional finishes. A low partition has the advantage of avoiding a feeling of being isolated, even though it is not the best partition in an electronic office.

Recessed lights can be used in the fire-rated ceiling assemblies of the *Economical Model* with fire protective covers. Covering materials include mineral-fiber board, mineral-wool blanket, and mineral-wool batt etc.. However, recessed lights are not suitable in an environment full of computer terminals. A computer screen is both a light source and a mirror. Like a mirror, it reflects light coming from any direction. Recessed lights with fluorescent downlights create bright spots on the ceiling, which also reflect on screens. Eye fatigue and strain are the effects of glaring problems in many existing buildings. The advantage of recessed lights is that they can be used as air-return luminaires. With a one-to-one ratio of workers per keyboard device in the future, each workstation has become its own heat source. It has been suggested that the heat load of a computer terminal is about the same as adding another person to the work area. With the achievement in superconductors, computers will generate less heat caused by electrical resistance and the demand on air-conditioning will be reduced.

For shadowless and glare-free environment, diffused lights are recommended to be used especially in the *Economical Model* with less disruption to the fire-rated ceilings. A diffused light can be suspended from a ceiling or mounted on an overhead cabinet and directs light toward the ceiling. The fixture can be designed with a series of prisms that disperses light evenly on the ceiling or upper wall, and redirects it back down over work areas. The ceiling and upper walls in effect become the light source and if these surfaces have a highly reflective finish, the illumination is quite diffuse. These types of lighting fixtures are also called indirect lighting, because all the light reaches the horizontal working plane indirectly. The spacing of the lighting fixtures, the suspension length and the valance dimensions must be carefully chosen to avoid excessive ceiling brightness. Supplementary lighting fixtures are usually required for additional task lighting. A diffused light, with air-return flexible ducts connected to the ceiling, is suggested to be used in the proposed floor systems for especially work places with electronic equipment (Figure 16 & 17 on page 97 & 98). With the *Economical Model*, the ducts can be protected with fire-rated dampers at the ceiling level for safety. An air-inlets are also suggested for the lower surface of the fixtures to remove hot air within the work places.

Vinyl and carpet are suggested surface finishes for the floor tiles. A resilient carpet is recommended for acoustical isolation. Vinyl and carpet can be manufactured according to the dimensions of the floor tiles. They are then glued down on top of the tile surfaces. Natural stones, such as marble and granite, can be used in certain area such as lobby and public area which require accessibility. Natural stones are diamond sawn into non-slip surfaces for the finishes of the accessible floor tiles. They are then glued down to the floor tiles with an adhesive such as a two-part epoxy resin. As for the outlets in lightweight concrete panels, floor tiles can be diamond cored after bonding the natural stone slabs on the tiles for outlet holes. Cores holes are then used as either power outlets or air-conditioning grilles. The location of the floor outlets can be designed according to the layout of the furniture; however, each outlet is recommended to be located in the center of a two-foot grid. One of the major problems in an automated building is static electricity. Static electricity is created by induction charging and contact charging. Induction charging occurs when electrical fields radiate from the surfaces of materials, and contact charging occurs when electrical fields radiate from two materials making contact and then separate, causing one material to strip electrons from the other. Electrostatic charge can destroy the computer memory or disturb the computer circuits. Various safeguards can be used such as placing grounding between each electronic device and the main system-earth connection, avoiding synthetic carpets, using antistatic mats adjacent to equipment, using earthed carpets and installing ionisers or negative ion generators, i.e. many electronic equipment and air-conditioning ducts are positively charged, these neutralize negative ions from ionisers that occur naturally in air. [7] The proposed floor tiles should be designed free of static electricity by grounding any conducting surfaces and by using suitable floor finishes.

Floor tiles are layed out according to the geometry of the floor plans (Figure 18 on page 99). Non-standardized floor tiles, such as pressure-impregnated fire-retardant treated plywood, are used in area such as the periphery of the floor plan. Plywood can be cut on the site with a circular saw according to the geometry of the floor plan. Non-standardized tiles are designed on the same level as standardized elements (2x2 or 4x4 floor tiles) to avoid the use of stair or ramp, especially for physically handicap. Non-standardized are recommended to be used in buildings with circular and curvilinear floor plans, i.e. the layout of interior walls are usually perpendicular to the tangent of the curvilinear exterior walls. Concrete on metal decks, precast concrete slabs or pour-in-place concrete slabs can be used for corridors and bathrooms within the stair towers. With the *Economical Model*, a dry construction is recommended for areas outside the stair towers with no pouring of in-situ concrete.

The idea behind the accessible floor tiles is to provide "instant flexibility" for workers without waiting for electricians. *Sunken floors* have a much lower life-cycle-cost analysis, as compared with flat cables. The individual should have the opportunities in the layout of his or her adjustable furnishings and equipment. To personalize the workplace, they should feel like they were working in their own homes. Finally, technological advances are being made so rapidly that there is a constant demand in design and layout flexibility in the floors and ceilings, so that new equipment and connecting networks can be retrofit in the buildings for adaptability in the future.

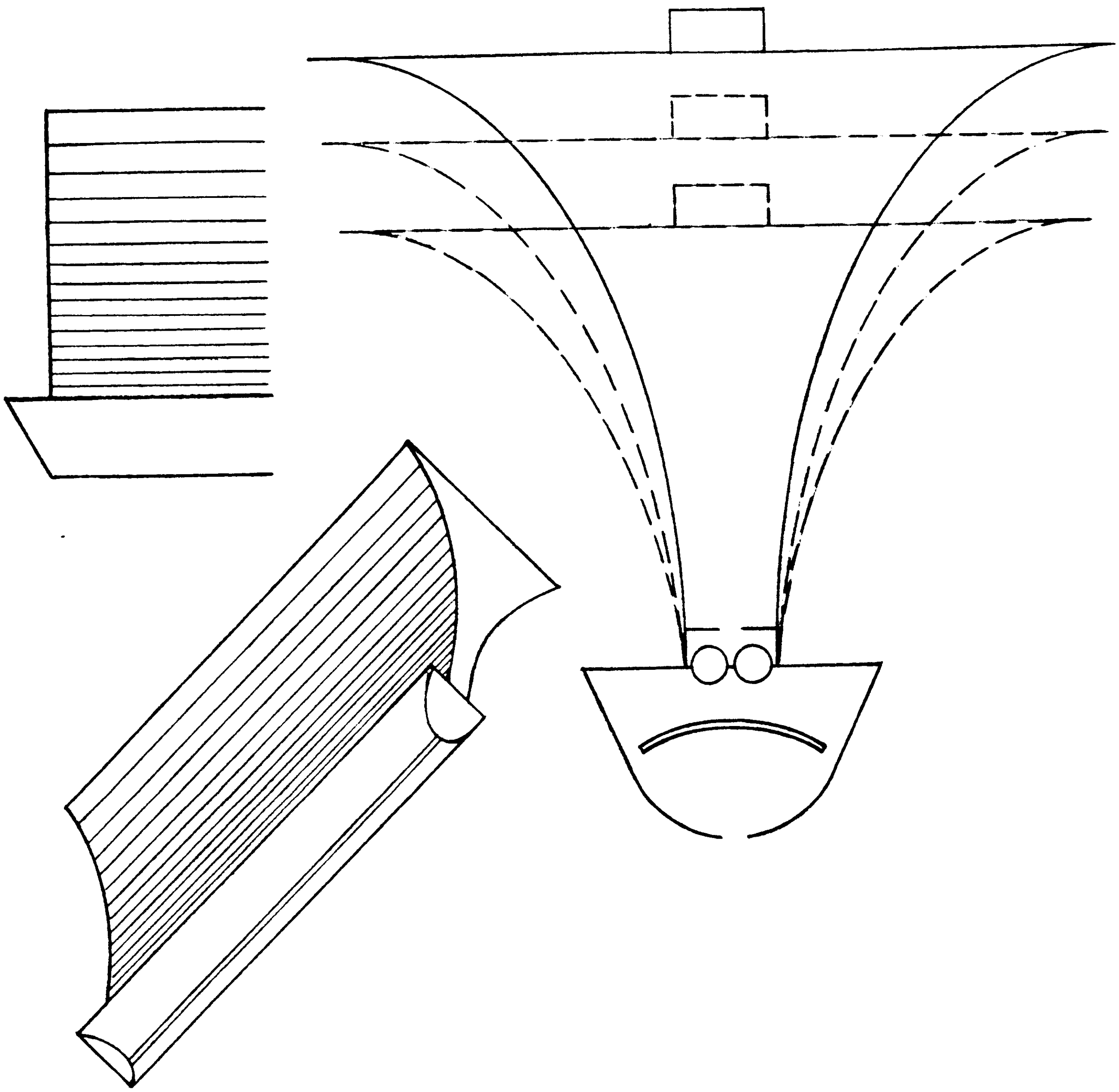


Figure 16:-

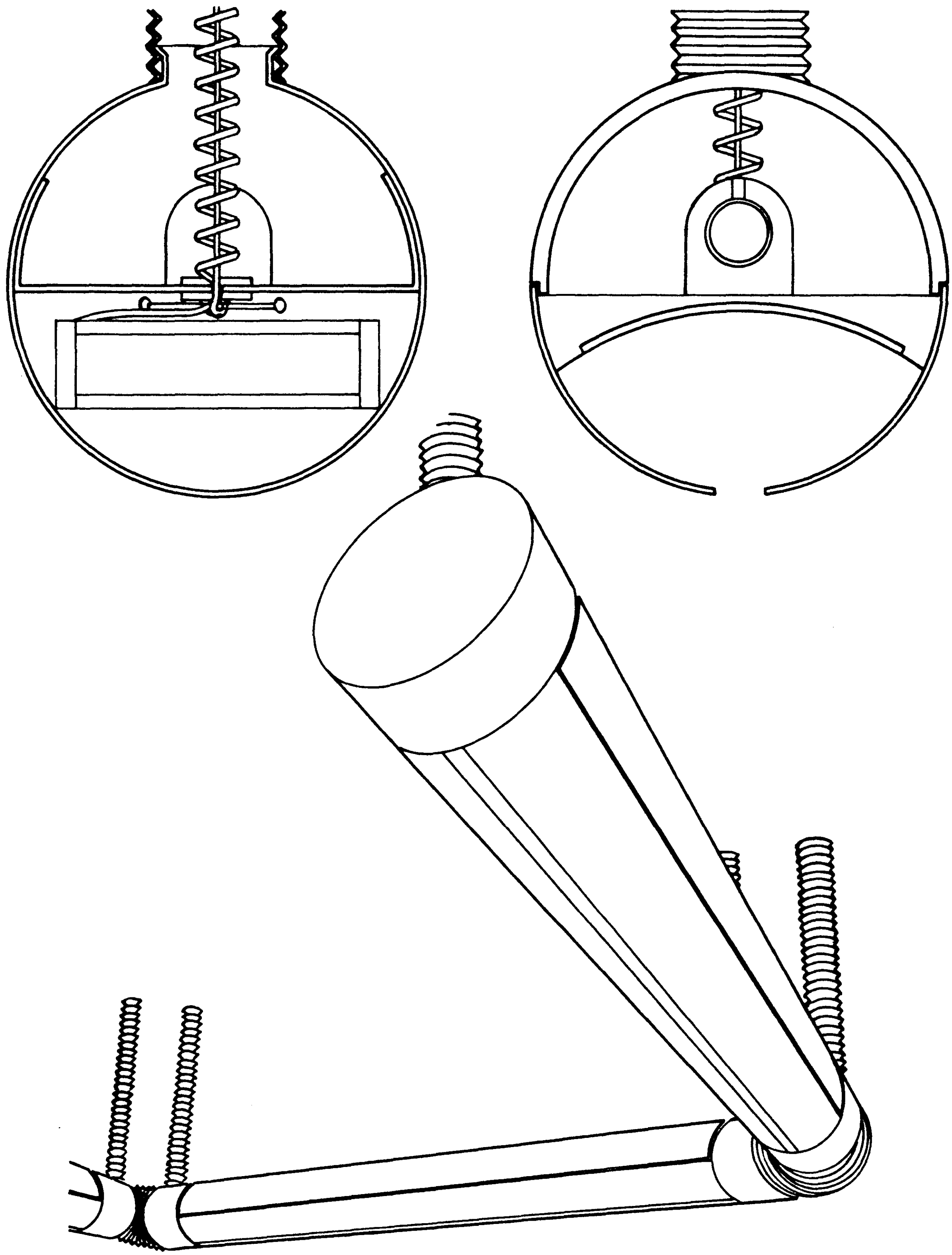
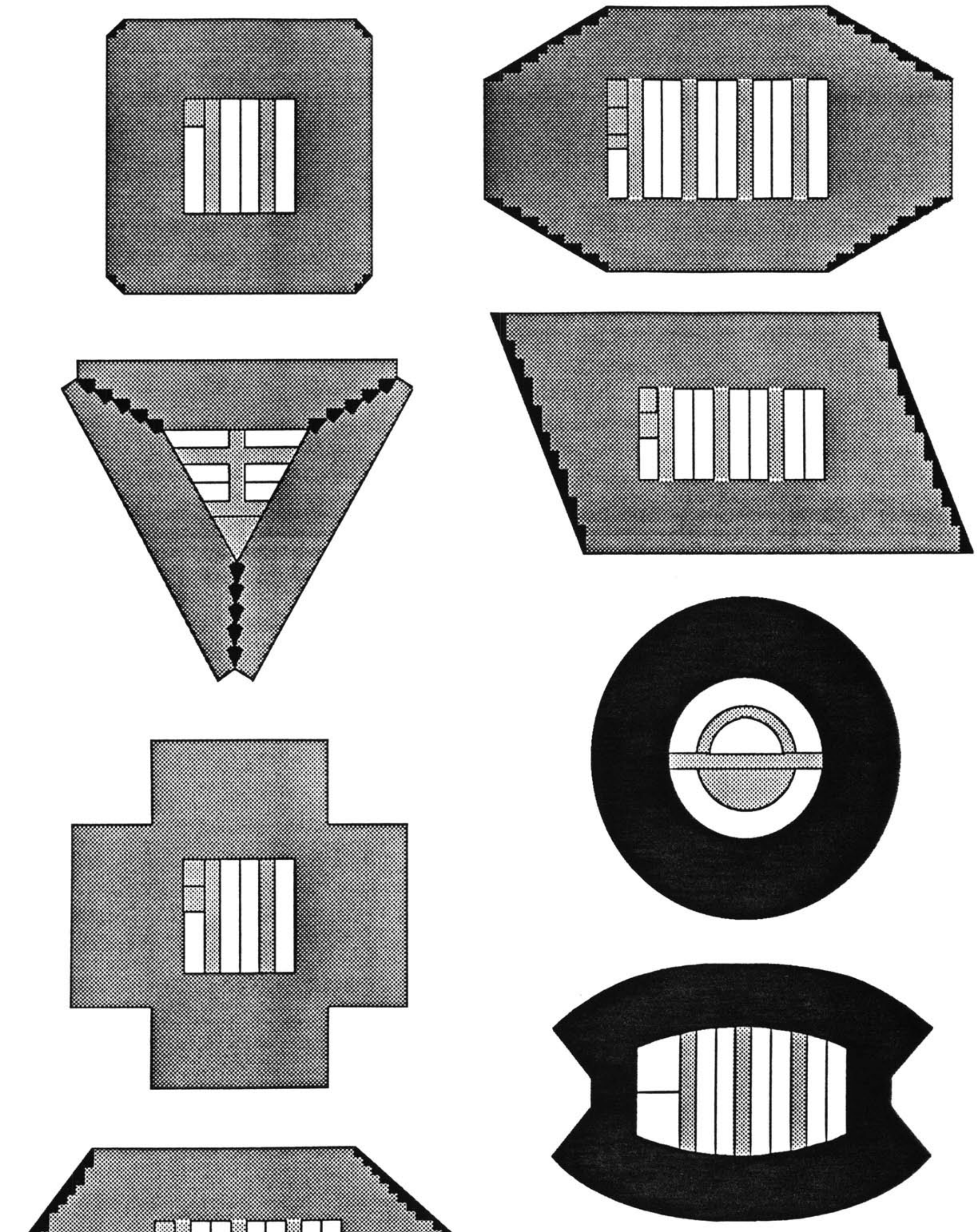


Figure 17:-



Typical floor plans

- Conventional floor slabs
- Accessible floor tiles
- Conventional slabs or non-standardized tiles

Figure 18

Chapter 10 *Conclusion*

"The increasing demand for flexibility and for greater complexity of services will increase the popularity of the proposed floor systems."

The design of the proposed floor systems is based on the existing raised floor systems. There are several existing multi-story office buildings which are designed with raised floor systems, i.e. The Hong Kong and Shanghai Bank in Hong Kong designed by Foster Associates; The Lloyd Wright Building in London designed by Richard Rogers & Partners Ltd. These buildings have higher initial costs and longer construction cycles than any conventional office buildings with the same floor areas; on the other hand, they are designed for upgrading with the new technologies.

The idea of an access floor orginated in the Oriential floor mat which is made of packed stiff rice-straw, i.e. *tatami* in traditional Japanese houses. *Tatami* is a standardized element with several different dimensions. Although *tatami* has have never functioned as a module of any kind in Japanese houses, its size is governed by the amount of clearance between columns. It automatically determines the number of possible room sizes in traditional Japanese framing. The floor mats are directly laid on top of the floor joists and beams. The mats are frequently rearranged according to the season or to a particular occasion.

Another idea behind the *Sunken Floor Systems* is flexibility. Flexibility is not free; the initial cost of a flexible building is higher than that of a non-flexible building, so that it may adapt to changing technology. On the other hand, a flexible system is usually provided with a more affordable life-cycle-cost analysis than a non-flexible building.

The cost per square foot of the *Economical Model* for a typical office could be from $70.00 to $90.00 per square foot, excluding siteworks, public areas and garage. The proposed systems are highly compatible with in-situ concrete on cellular metal decks (refer to Table 1 on page 104). The *Economical Model* requires more spending on the fire-rated ceiling; however, there will be a reduction in spending on wall materials and foundations with friction piles or ball bearing piles. An affordable life-cycle-cost analysis will also bring in some saving. These reductions in spending are not included in the cost analysis (refer to Table 1). The proposed systems are highly recommended for multi-story office buildings with repetitive floors, which are designed with the same layout and construction method. The trade-off in the proposed systems is floor deflection which is related to human comfort. Human reponse to vibrating floors should be carefully studied, especially in a multi-story building constantly under wind loads. As mentioned earlier, damping sources such as demountable interior partitions should be provided in the interior design and planning.

The cost per square foot of the *Supreme Model* for a typical office could be from $80.00 to $110.00 per square foot, excluding siteworks, public areas and garage (refer to Table 2 on page 105). The cost per square foot for a clean room could be as high as $1,000.00 per square foot with extensive mechanical equipment. It is not recommended to use the *Supreme Model* for the entire areas of a building with a number of repetitive floors. The *Supreme Model* costs more than the *Economical Model* with extra spending on the permanent floor slabs. Therefore, it is recommended to use the *Supreme Model* for that part of the building which requires functions such as security or cleanliness. The idea is similar to interstitial floors for the surgicial rooms, diagnostic centers and laboratories of a hospitial, with patient-housing and administrative areas designed on conventional slabs. If floor-to-floor height is not a limitation for low-rise and mid-rise buildings, modified solid I-beams can be used for facilities such as clean rooms to speed up the construction. Clean rooms used in the manufacture of microchips must be designed to be vibration-free; in this case, in-situ concrete slab is preferred to achieve mass and stiffness. An increase in slab thickness will improve the vibration characteristics of a floor by increasing the effective stiffness transverse to the joists. A in-situ concrete slab is suggested to cast on temporary plywood formworks. The formworks are supported by roll bars which are locked into the notches in the trusses or beams. Accessible floor tiles are designed with perforated holes for a laminar-flow system. The air travels vertically from ceiling to floor in a unidirectional pattern that permits the particles in the air to be carried away as soon as possible.

The efficiency of the proposed access floors should be incorporated with appropriate wire management and periodical inspection. Old data cables and telephone wires should be disconnected and removed from the plenums by the tenants or owners. A fire-rated ceiling should be renovated and inspected according to the guidelines and specifications. One of the dangers in the proposed systems is a mismatch between the designer's intent and the owner's use of the product, which is likely to occure in any flexible system with poor management. An individual who ignores the potential danger could easily mistreat the flexible components. Under this circumstance, building owners or tenants should be heavily fined by the local authority if there is a violation in building safety. A reliable sprinkler system should be installed in all buildings with the *Economical Model.* If someone violates the integrity of the fire-rated ceilings, a fire will not spread so rapidly from floor to floor with the sprinklers.

To sum up, the *Sunken Floor Systems* are not the only answer for telecommunications. There are some minor drawbacks in the systems. The advantage is the "instant flexibility" in upgrading with new electronic and mechanical services. The practice of rearranging workstations and of more workstations being outfitted with terminals will influence the growing use of the proposed floor systems. Futhermore, the proposed systems have affordable initial and life-cycle-cost analysis for general office and commercial usages. The increasing demand for flexibility and for greater complexity of services will increase the popularity of the proposed floor systems; in addition, their popularity will eventually end up with a reasonable price tag in the near future.

Economical Model Cost Analysis (Table 1) (based on 1987 Means Const. Cost Data w/ 200,000 S. F. office areas for a 10 story building with a 11 feet floor-to-floor height)	Cost per unit	Total units	Total unit costs	Cost per S. F.
Open web joists - LH series w/ cross bridgings	1,300	766	$995,800.00	
	($/ton)	(ton)		
Access 4'x4' steel panels with lightweight conc. and stringer system	7	200,000	$1,400,000.00	
	($/S.F.)	(S.F.)		
Fire-retardant intumescent coating on stringers	0.5	200,000	$100,000.00	
	($/S.F.)	(S.F.)		
Structural columns w/ 5/8 gyp. fireproof.	1.05	200,000	$210,000.00	
	($/S.F.)	(S.F.)		
Roof w/ metal deck, open web steel joists, beams and columns	0.21	200,000	$42,000.00	
	($/S.F.)	(S.F.)		
Footings & foundations - strip & spread footings and 4' foundation walls	1.02	200,000	$204,000.00	
	($/S.F.)	(S.F.)		
Excavation & backfill for foundation walls & footings	0.05	200,000	$10,000.00	
	($/S.F.)	(S.F.)		
4" reinforced concrete slab on grade w/ vapor barrier and granular base	0.16	200,000	$32,000.00	
	($/S.F.)	(S.F.)		
Stairs w/ concrete filled metal pans	1.16	200,000	$232,000.00	
	($/S.F.)	(S.F.)		
4'x4' resilient carpet coverings	2.48	200,000	$496,000.00	
	($/S.F.)	(S.F.)		
Optional steel decking, 28 guage, 9/16"deep	0.54	180,000	$97,200.00	
	($/S.F.)	(S.F.)		
Thermal or acoustical batt above acoustical ceilings, 2" thick	0.57	180,000	$102,600.00	
	($/S.F.)	(S.F.)		
Accessible ceiling tile system	2.75	200,000	$550,000.00	
	($/S.F.)	(S.F.)		
Interior partitions, doors and wall finishes	3.3	200,000	$660,000.00	
	($/S.F.)	(S.F.)		
Mechanical & electrical supplies	21	200,000	$4,200,000.00	
	($/S.F.)	(S.F.)		
Curtain walls, aluminium, stock, including glazing	24	62,225	$1,493,400.00	
	($/S.F.)	(S.F.)		
Roofing - built-up tar & gravel with fiber-board insulation	0.32 ($/S.F.)	200,000 (S.F.)	$64,000.00	
Conveying - 6 passenger elevators	6.31	200,000	$1,262,000.00	
	($/S.F.)	(S.F)		
Sub-total			$12,151,000.00	
General conditions (overhead & profit),15%			$1,822,650.00	
Architectural fees, 6%			$838,419.00	
TOTAL COST FOR OFFICE AREAS (not incl. sitework, public areas and garage)			$14,812,069.00	74.060345 ($/S.F.)

Supreme Model Cost Analysis (Table 2) (based on 1987 Means Const. Cost Data w/ 200,000 S. F. office areas for a 10 story building with a 11 feet floor-to-floor height)	Cost per unit	Total units	Total unit costs	Cost per S. F.
Composite web joists	1,700 ($/ton)	957.5 (ton)	$1,627,750.00	
Concrete slab, metal deck, beams	8.8 ($/S.F.)	200,000 (S.F.)	$1,760,000.00	
Access 4'x4' steel panels w/ lightweight concrete	6.5 ($/S.F.)	200,000 (S.F.)	$1,300,000.00	
Structural columns w/ 5/8 gyp. fireproof.	1.05 ($/S.F.)	200,000 (S.F.)	$210,000.00	
Roof w/ metal deck, open web steel joists, beams and columns	0.21 ($/S.F.)	200,000 (S.F.)	$42,000.00	
Footings & foundations - strip & spread footings and 4' foundation walls	1.02 ($/S.F.)	200,000 (S.F.)	$204,000.00	
Excavation & backfill for foundation walls & footings	0.05 ($/S.F.)	200,000 (S.F.)	$10,000.00	
4" reinforced concrete slab on grade w/ vapor barrier & granular base	0.16 ($/S.F.)	200,000 (S.F.)	$32,000.00	
Stairs w/ concrete filled metal pans	1.16 ($/S.F.)	200,000 (S.F.)	$232,000.00	
4'x4' resilient carpet coverings	2.48 ($/S.F.)	200,000 (S.F.)	$496,000.00	
Ceiling tile system	2.71 ($/S.F.)	200,000 (S.F.)	$542,000.00	
Interior partitions, doors and wall finishes	3.3 ($/S.F.)	200,000 (S.F.)	$660,000.00	
Mechanical & electrical supplies	19 ($/S.F.)	200,000 (S.F.)	$3,800,000.00	
Curtain walls, aluminium, stock, including glazing	24 ($/S.F.)	62,225 (S.F.)	$1,493,400.00	
Roofing - built-up tar & gravel with fiber-board insulation	0.32 ($/S.F.)	200,000 (S.F.)	$64,000.00	
Conveying - 6 passenger elevators	6.31 ($/S.F.)	200,000 (S.F.)	$1,262,000.00	
Sub-total			$13,735,150.00	
General conditions (overhead & profit),15%			$2,060,272.50	
Architectural fees, 6%			$947,725.35	
TOTAL COST FOR OFFICE AREAS (not incl. sitework, public areas and garage)			$16,743,147.85	83.715739 ($/S.F.)

	Economical Models
	Structures Vs Mechanical
Integration	* Appropriate spanning for duct penetrations.
	* Integration of duct sizes and air-flow with web openings.
Visual	* No visual characteristic from the floor above or below.
Performance	* Acoustical and air handling performance Vs structural layouts and mechanical design.
Economy	* Reduction in spending on building materials with additional spending on web openings.
Limitations	* Duct sizes and shapes are limited by web openings.
	* Require appropriate bay sizes and joist spanning for duct penetrations.
	Structures Vs Telecommunications
Integration	* Penetration of power, electronic and communication cables with web openings.
Visual	* No visual characteristic from floor above or below.
Performance	* Flexibility in renovation.
Economy	* Initial spending on the web openings.
	* Reduction in spending on wiring renovation and addition.
Limitation	* Require organization of cables in open plenums.
	* Electrical conduits have to be grounded and insulated from structures.
	* Limitation on floor-to-floor security with data cables - fiber optic cables are recommended.
	Structures Vs Lightings
Integration	* Lightings are suspended from structures with furring channels
	* Installation and fixing of lighting fixtures from the floor below.
Visual	* Alignment of lightings with acoustical ceilings.
Performance	* Lighting design and ceiling height.
Economy	* Additional spending on fixture protection for fire-rated ceilings.
	* Reduction in spending on air handling luminaires.
Limitation	* Careful renovation of ceiling lights to ensure fire integrity of floors.
	Structures Vs Acoustical Ceilings
Integration	* Fire-rated ceilings suspended from structures.
Visual	* Leveling of acoustical ceilings with structures.
Performance	* Fire protection and acoustical isolation for structures.
Economy	* Extra spending on safety nets and ceramic fiber blankets.
Limitation	* Careful renovation of ceiling layouts to ensure fire integrity of floors.
	Structures Vs Floor Panels
Integration	* Panel sizes Vs appropriate spacing for structures.
	* Acoustical and vibrational isolation with dampers in floor anchors.
Visual	* Aesthetic design of finished layers.
Performance	* No leveling is required.
Economy	* Fast construction cycle with appropriate space planning.
	* Reduction in spending on structural and possibly foundation design with less dead loads.
Limitation	* Horizontal bracings are required.
	* Tighter floor-to-floor securities are required.
	* Perforated panel is not recommended.
	Mechanical Vs Recessed Lightings
Integration	* Location of air handling luminaires.
	* Lightings and air conditioning induce a temperature gradient.
Visual	* Aesthetic design of air handling luminaires
Performance	* Temperature gradient related with the rate of air exhaust through the ceilings.
Economy	* Reduction in spending on mechanical and improvment on the efficiency of lightings.

Limitation	* Air return is limited to area with artificial lightings.
	* Required fire protection with openings for mechanical.
	Mechanical Vs Acoustical Ceilings
Integration	* Layouts of mechanical outlets Vs location of acoustical tiles.
	* Fire protection with air dampers for mechanical openings.
Visual	* Layouts and aesthetic design of acoustical ceilings and mechanical outlets.
Performance	* Efficiency of air conditioning Vs height of acoustical ceilings.
Economy	* Sizes and types of outlets Vs acoustical layouts.
	* Spending on air dampers.
Limitation	* Careful workmanship to ensure fire integrity of floors.
	* Limitation on heating cycle with air supply and return through the ceilings.
	Telecommunications Vs Floor Panels
Integration	* Location of floor outlets Vs location of power, electronic and communication cables.
Visual	* Layouts and aesthetic design of floor outlets with floor panels.
Performance	* Flexibility in relocation of floor outlets by flexible conduits and rotation of tiles.
Economy	* Reduction in spending on wiring relocation and renovation.
Limitations	* Floor-to-floor data cables security.
	* Organization of cable layouts.
	Recessed Lightings Vs Acoustical Ceilings
Integration	* Location of recessed lighting Vs ceiling layouts.
	* Fire protection with fixture enclosure.
Visual	* Lightings, acoustical tiles layout and aesthetic design.
Performance	* Efficiency of lighting design Vs height of acoustical ceilings.
Economy	* Types of recessed lighting Vs ceiling layouts.
	* Extra spendings on fire protection.
Limitation	* Careful workmanship to ensure fire integrity of floor.

	Supreme Models
	Structures Vs Mechanical
Integration	* Appropriate spanning for duct penetrations.
	* Integration of duct sizes and air-flow with web openings.
	* Possible separation between air supply and return outlets with floor diaphragms.
Visual	* No visual characteristic from the floor above or below.
Performance	* Acoustical and air handling performance Vs structural layouts and mechanical design.
Economy	* Reduction in spending on duct installation with pressurized plenums.
Limitations	* Duct sizes and shapes are limited by web openings.
	* Require appropriate bay sizes and joint spanning for duct penetrations.
	* No limitation on pressurized plenums.
	Structures Vs Telecommunications
Integration	* Penetration of power, electronic and communication cables with web openings.
Visual	* No visual characteristic from floor above or below.
Performance	* Flexibility in renovation.
	* High floor-to-floor security with data cables.
Economy	* Initial spending on the web openings.
	* Reduction in spending on wiring renovation and addition.
Limitation	* Require organization of cables in open plenums.
	Structures Vs Recessed Lightings
Integration	* Lightings are suspended from structures with furring channels.
Visual	* Alignment of lightings with acoustical ceilings.
Performance	* Lighting design and ceiling height.
Economy	* Reduction in spending on air handling luminaires.
Limitation	* No significant limitation.
	Structures Vs Acoustical Ceilings
Integration	* Acoustical ceilings suspended from structures.
Visual	* Leveling of acoustical ceilings with structures.
Performance	* Acoustical isolation for structures with optional fire protection from fire-rated ceilings.
Economy	* Depends on the types of acoustical ceilings.
Limitation	* No significant limitation
	Structures Vs Floor Panels
Integration	* Panel sizes Vs appropriate spacing for structures.
	* Acoustical and vibrational isolation with dampers in floor anchors.
	* Longer joist spanning with stronger floor slabs.
Visual	* Aesthetic design of finished layers.
Performance	* Faster construction with precast prestressed slabs.
	* No bridging is required.
	* No leveling is required.
	* Perforated panels and floor diaphragms can be used as pressurized plenums.
Economy	* Cost less than raised floors but more than conventional systems.
Limitation	* Slightly longer construction cycle.
	Mechanical Vs Recessed Lightings
Integration	* Location of air handling luminaires.
	* Lightings and air conditioning induce a temperature gradient.
Visual	* Aesthetic design of air handling luminaires.
Performance	* Temperature gradient related with the rate of air exhaust through the ceilings.
Economy	* Reduction in spending on mechanical and improvment on the efficiency of lightings.

Limitation	* Air return is limited to area with artificial lightings.
	Mechanical Vs Acoustical Ceilings
Integration	* Layouts of mechanical outlets Vs location of acoustical tiles
Visual	* Layouts and aesthetic design of acoustical ceilings and mechanical outlets.
Performance	* Efficiency of air conditioning Vs height of acoustical ceilings.
Economy	* Sizes and types of outlets Vs acoustical layouts.
Limitations	* Limitation on heating cycle with air supply and return through the ceilings.
	Telecommunications Vs Floor Panels
Integration	* Location of floor outlets Vs location of power, electronic and communication cables.
Visual	* Layouts and aesthetic design of floor outlets with floor panels.
Performance	* Flexibility in relocation of floor outlets by flexible conduits and rotation of tiles.
Economy	* Reduction in spending on wiring relocation and renovation.
Limitation	* Organization of cable layouts.
	Recessed lightings Vs Acoustical Ceilings
Integration	* Location of recessed lighting Vs ceiling layouts.
Visual	* Lightings, acoustical tiles layout and aesthetic design.
Performance	* Efficiency of lighting design Vs height of acoustical ceilings.
Economy	* Types of recessed lighting Vs ceiling layouts.
Limitation	* No limitation.

Appendix

Finite element analysis on the wind bracing and *Composite Web Joist* with the *GROWLTIGER* software.

The author would like to thank professor John Slater from the Department of Civil Engineering for contributing to the finite element analysis and structural design. These studies are intended to understand the behavior of the proposed structural systems under wind or live loads. It is not intended to draw any conclusive answer on the structural design of the new floor systêms. There are several framing systems and structural elements which can be used for the *Sunken Floor Systems*, their behavior under live or dead loads should be thoroughly analysed before any final decision is made.

The *Composite Web Joist* is analysed with a uniform live load of 100 pounds per square feet. The floor joist is slightly over-designed with a larger section for the lower chord. The end connections of the floor joist have the highest tendency to fail under shear stress; therefore, it is recommended to use two structural elements for the upper-top chords, i.e. welding two cold-formed channels at the end connections of the joist to increase the shear capacity. Certain buildings are designed with a heavier floor load for computing and manufacturing equipment, a hybrid beam or girder can be used to increase the live load, i.e., with A36 steel for the top flange and A514 steel for the bottom flange.

To find out the Allowable Bending Stress:-

$F_b = 0.66\ (F_y)$ A.I.S.C. F_y = Min. Yield Stress = 36 ksi (with A36 steel)

$= 0.66\ (36)$ F_b = Allowable Stress

$= 24$ ksi Factor of safety = 0.66

For example, check if working stress $< F_b$

Bending Stress + Compressive Stress $< F_b < 24$

Bending Stress = $\frac{M}{S}$ M = Moment in Member

S = Sectional Modulus

Compressive Stress = $\frac{F}{A}$ F = Compression Forecs in Member

A = Cross Sectional Area

The highest Fb for the *Composite Web Joist* in member 11 is 7.55 ksi < 24 ksi; therefore, member is stable.

To find out the allowable shear stress:-

$F_v < 0.4\ (F_y)$ A.I.S.C. F_y = Min. Yield Stress = 36 ksi (with A36 steel)

$< 0.4\ (36)$ F_v = Allowable Stress

< 14.4 ksi   Factor of Safety = 0.4

The highest Fv for the *Composite Web Joist* in member 19 is 5.07 ksi < 14.4 ksi; therefore, member is stable.

The wind load analysis is to demonstrate the effect of horizontal wind bracing under a constant wind load of 70 pounds per square foot. With a two dimensional computer software, the four columns are rotated on the same plane with the floor framing. Under the horizontal wind load, the floor framing acts as a diaphragm transmitting transverse loads into the frame and finally to the vertical shear walls or columns. Horizontal bracing increases the stiffness of the floor diaphragm, especially for the proposed floor systems with the absence of a permanent floor slab. By comparison, the columns with horizontal wind bracing carry less wind load than the one without bracing, i.e. axial force for the columns with bracing is 6.839 kips, without bracing is 6.932 kips. Finally, the stiffness of floor tiles is neglected in the wind load analysis to simply the structural calculation.

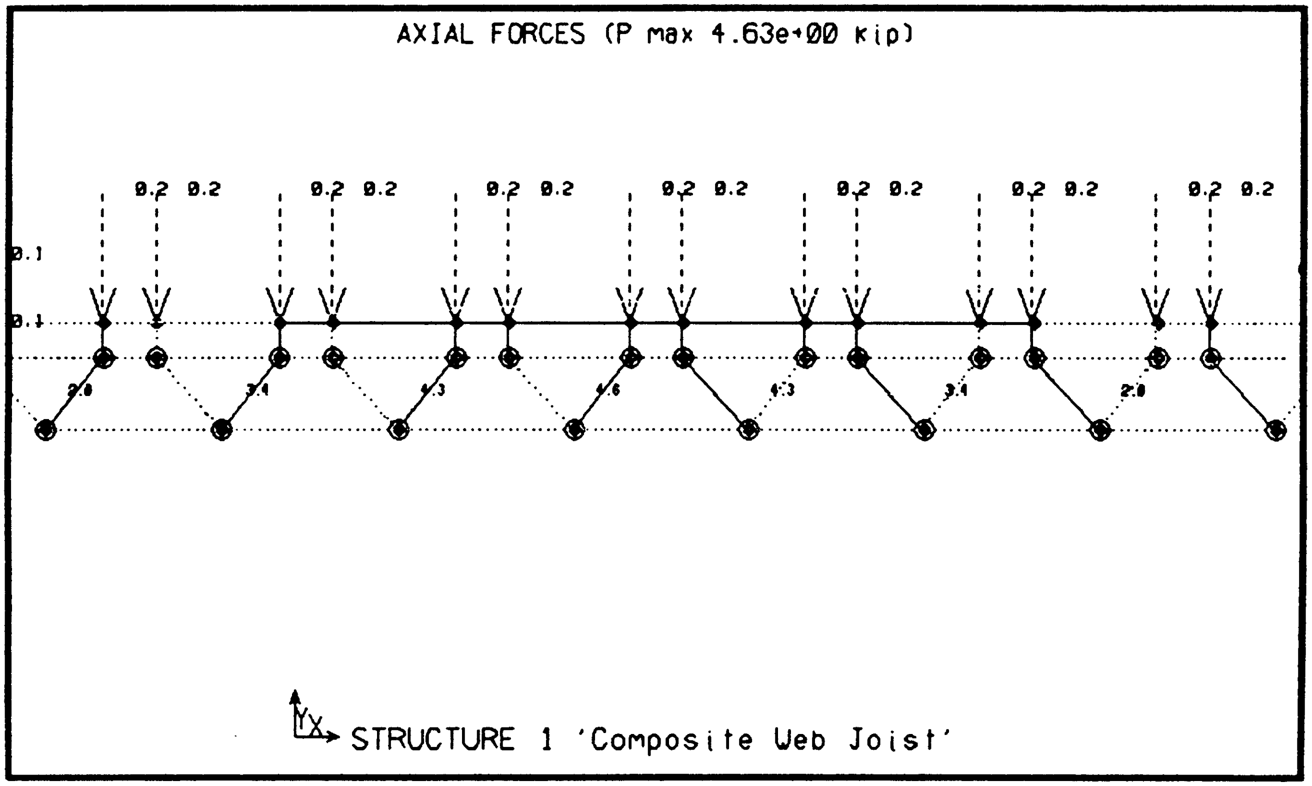
To find out the allowable tensional stress:-

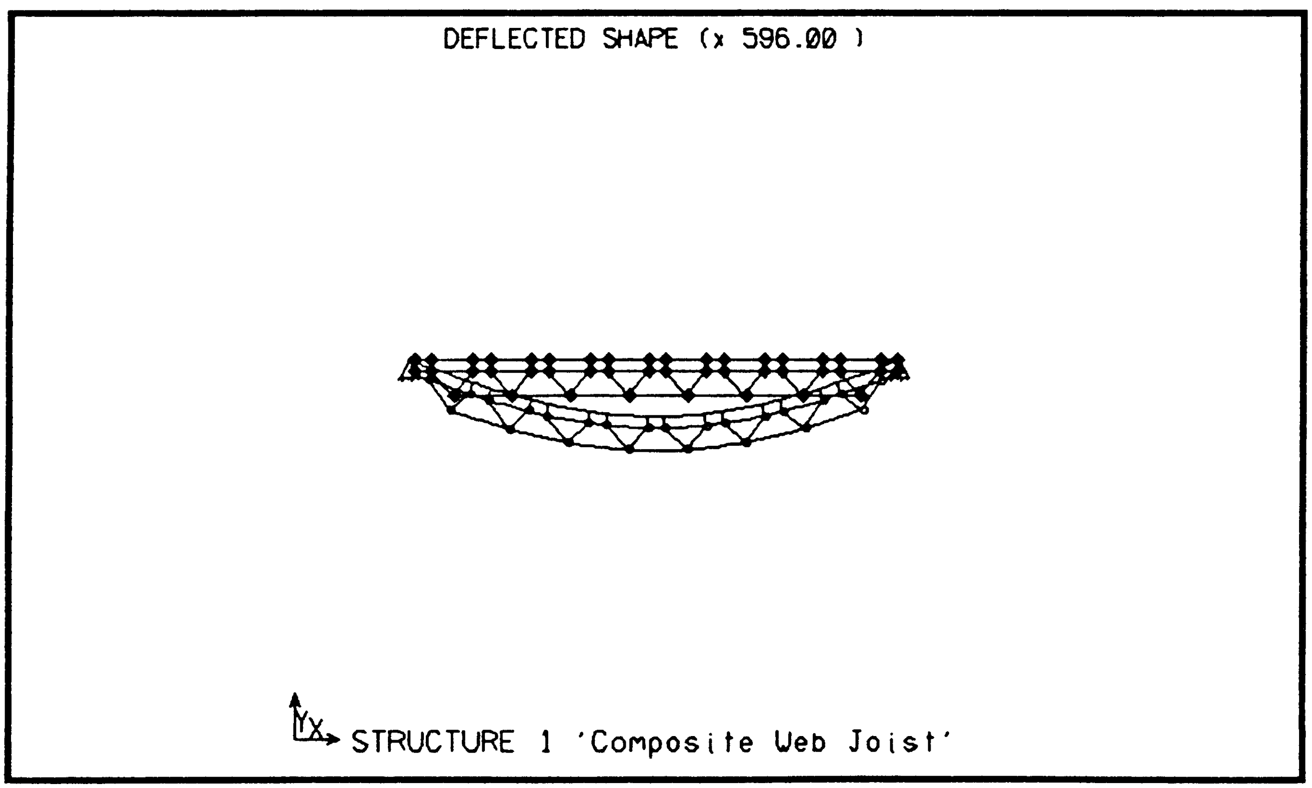
$F_t < 0.6\ (F_y)$ A.I.S.C. F_y = Min. Yield Stress = 36 ksi (with A36 steel)

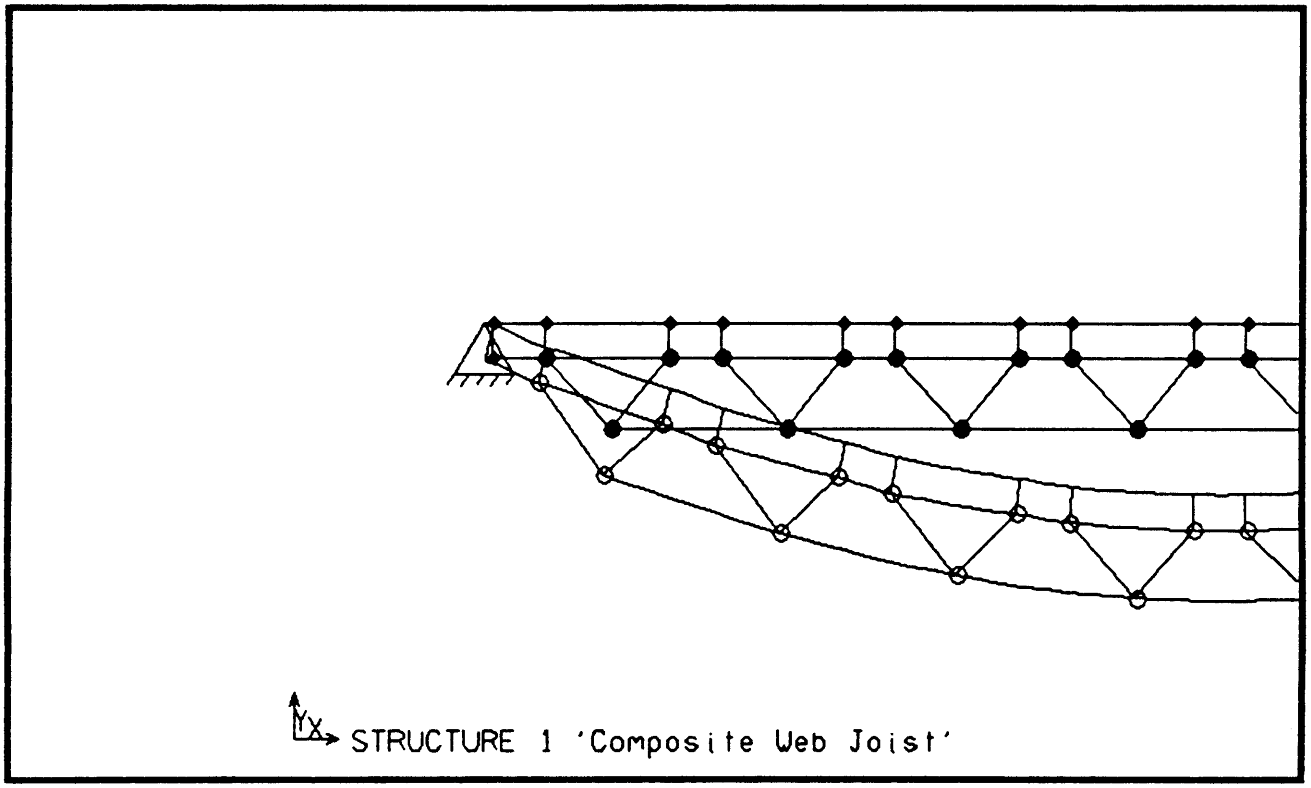
$< 0.6\ (36)$ F_t = Allowable Stress

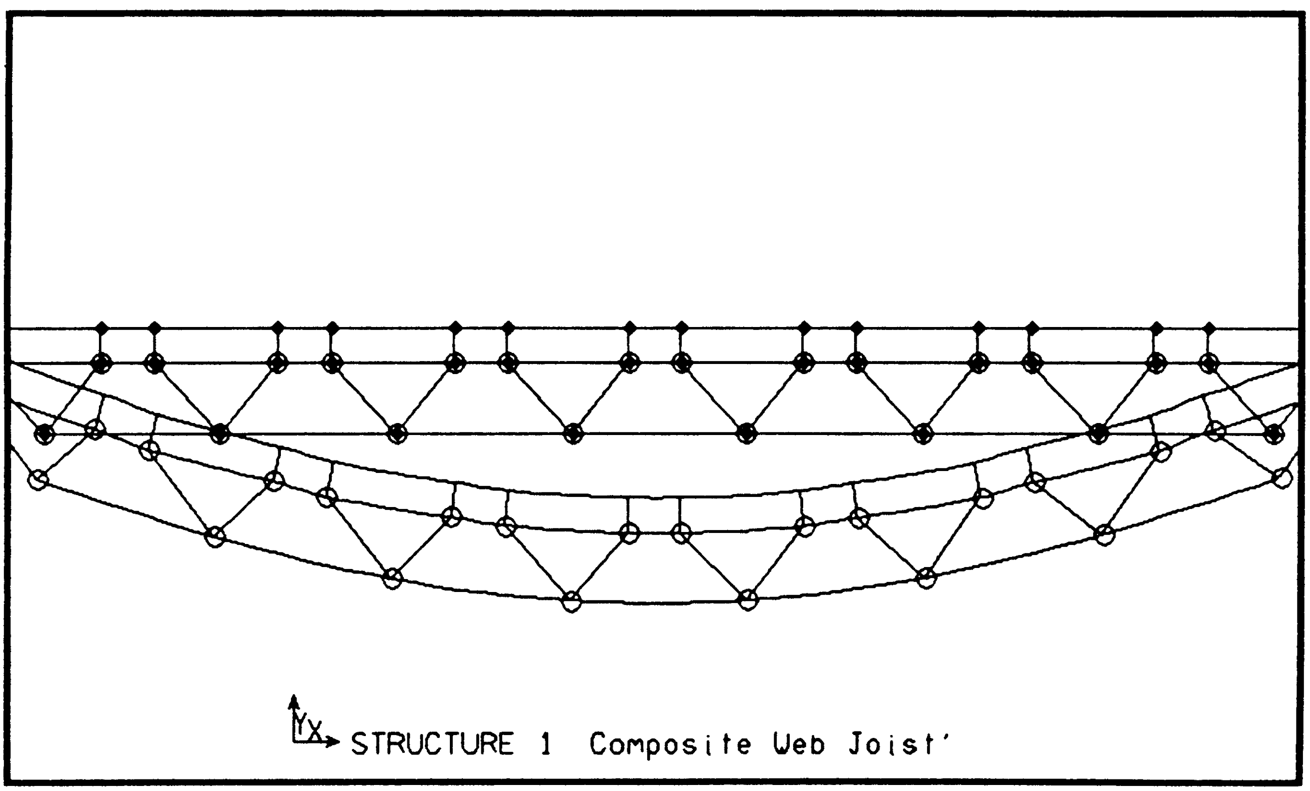
< 21.6 ksi   Factor of Safety = 0.6

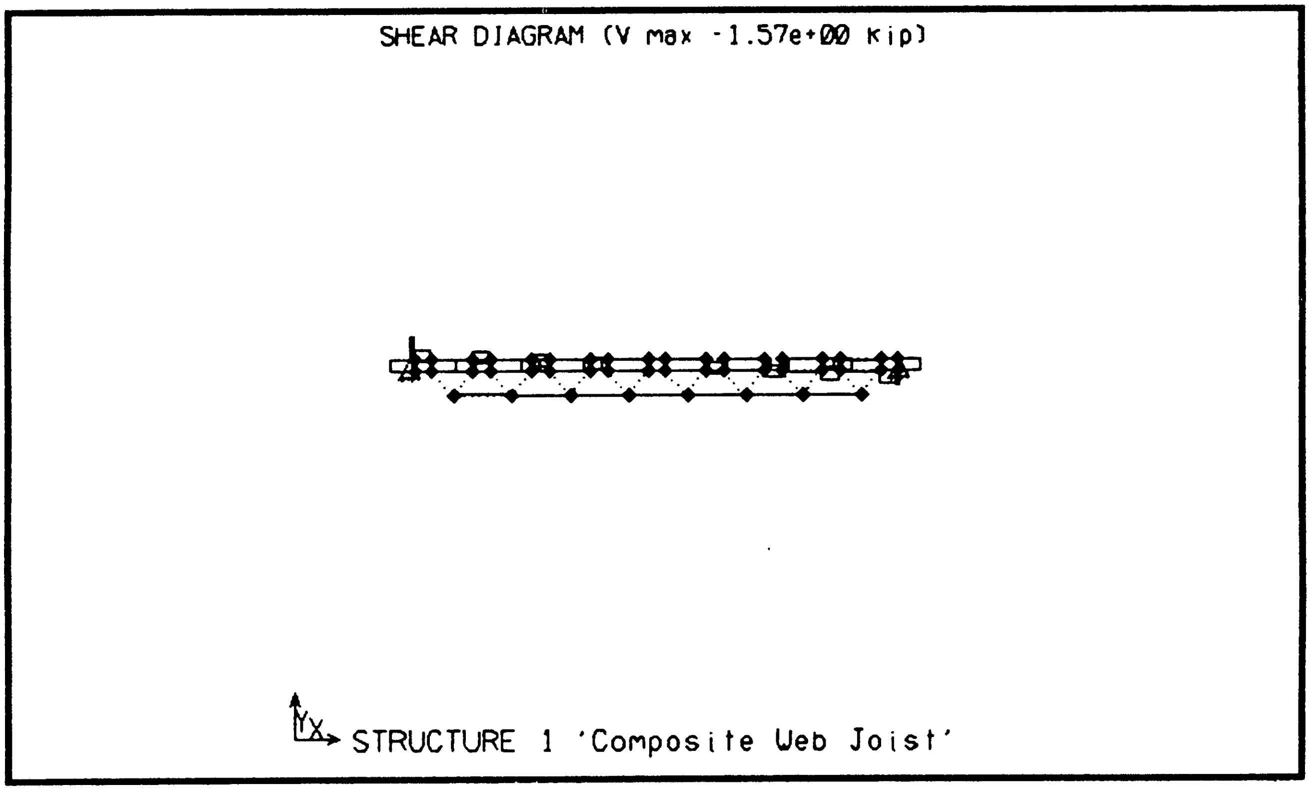
The highest Ft for the columns without bracing in member 1 & 102 is 15.52 ksi < 21.6 ksi; therefore, columns are stable.

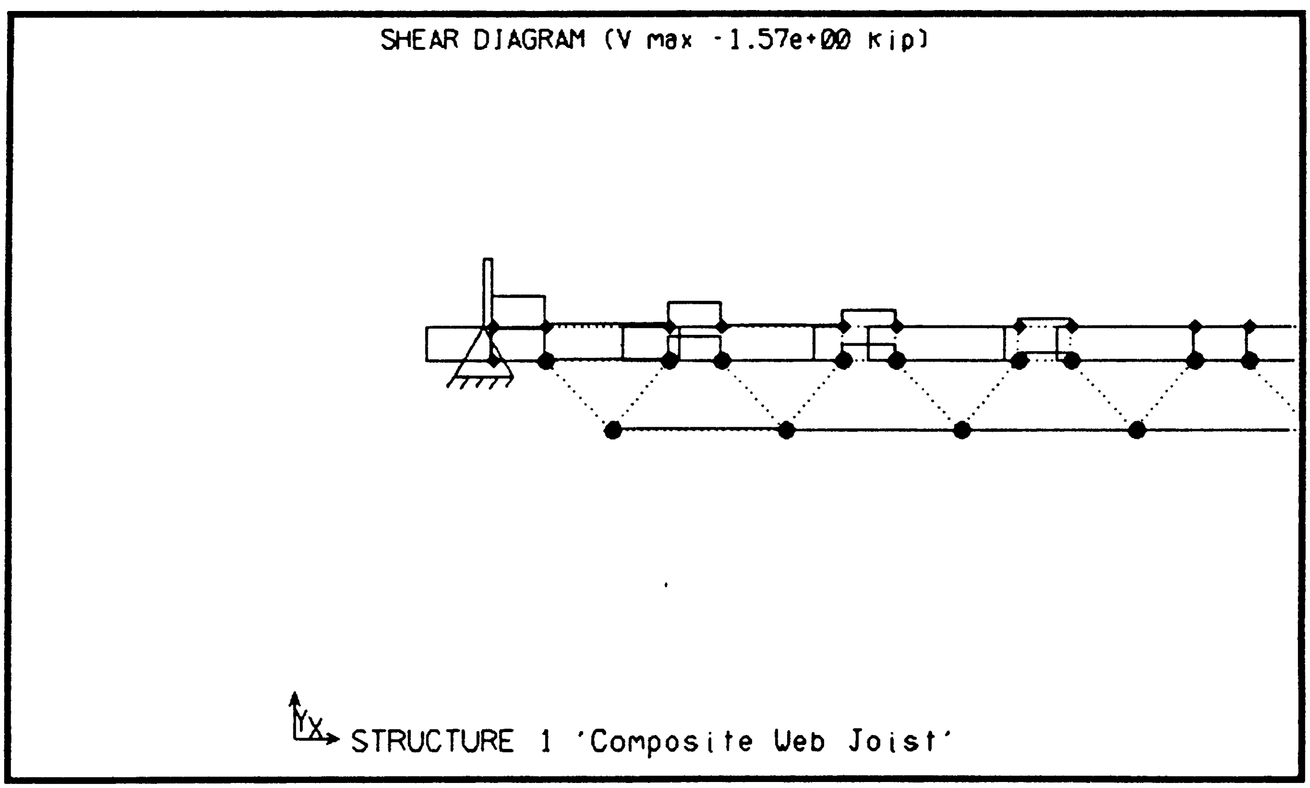


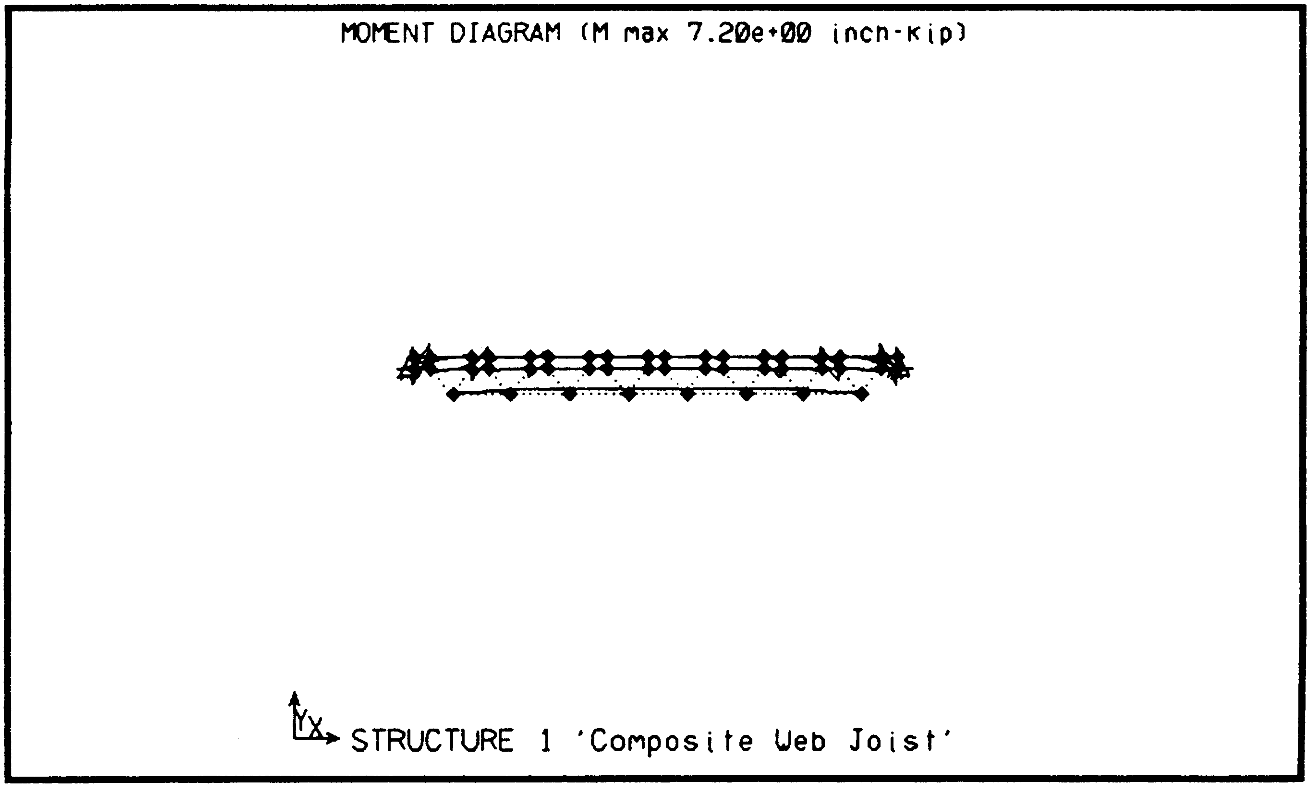


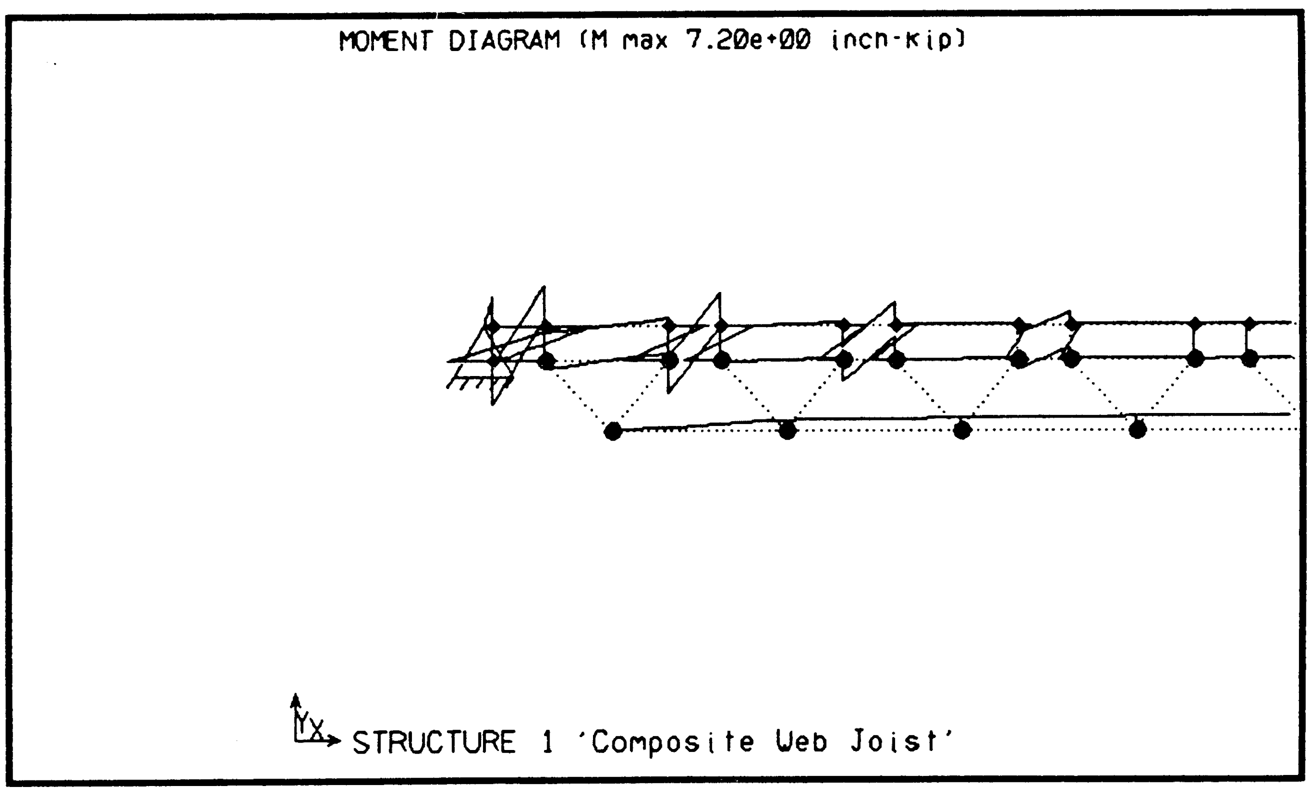

STRUCTURE 1 'Composite Web Joist'


STRUCTURE 1 Composite Web Joist'


SHEAR DIAGRAM (V max -1.57e+00 kip)
STRUCTURE 1 'Composite Web Joist'


SHEAR DIAGRAM (V max -1.57e+00 kip)
STRUCTURE 1 'Composite Web Joist'


MOMENT DIAGRAM (M max 7.20e+00 incn-kip)
Y X
STRUCTURE 1 'Composite Web Joist'


MOMENT DIAGRAM (M max 7.20e+00 incn-kip)
Y X
STRUCTURE 1 'Composite Web Joist'

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MEMBER FORCES AND MOMENTS STRUCTURE 1 'Composite Web Joist
LOADING: CASE 1 2D UNITS: LENGTH (inch) FORCE (kip)

****

MEMBER	NODES		AXIAL_FORCE	START_SHEAR END_SHEAR	START_MOMENT END_MOMENT	MAX_MOMENT X_MAX	SPAN_MOMENT
1	1	2	4.349e+00	1.405e+00 1.405e+00	0.000e+00 2.810e+00	2.810e+00 2.000e+00	2.810e+00
2	2	3	2.994e+00	6.388e-01 6.388e-01	3.849e+00 3.817e+00	-3.849e+00 0.000e+00	-3.849e+00
3	3	4	1.847e+00	4.973e-02 4.973e-02	7.103e-01 6.821e-01	-7.103e-01 0.000e+00	-7.103e-01
4	4	5	9.156e-01	5.088e-01 5.088e-01	3.022e+00 3.083e+00	3.083e+00 1.200e+01	3.083e+00
5	5	6	1.000e-01	1.583e-02 1.583e-02	1.545e-01 2.888e-01	2.888e-01 2.800e+01	2.888e-01
6	6	7	-4.736e-01	3.458e-01 3.458e-01	1.990e+00 2.160e+00	2.160e+00 1.200e+01	2.160e+00
7	7	8	-1.004e+00	4.153e-03 4.153e-03	-5.500e-02 1.713e-01	1.713e-01 2.800e+01	1.713e-01
8	8	9	-1.280e+00	1.734e-01 1.734e-01	9.257e-01 1.155e+00	1.155e+00 1.200e+01	1.155e+00
9	9	10	-1.540e+00	4.373e-04 4.373e-04	-1.283e-01 1.406e-01	1.406e-01 2.800e+01	1.406e-01
10	10	11	-1.546e+00	2.041e-03 2.041e-03	-1.119e-01 1.364e-01	1.364e-01 1.200e+01	1.364e-01
11	11	12	-1.547e+00	-1.041e-04 -1.041e-04	-1.372e-01 1.343e-01	1.372e-01 0.000e+00	1.372e-01
12	12	13	-1.295e+00	-1.693e-01 -1.693e-01	-1.131e+00 -9.006e-01	1.131e+00 0.000e+00	1.131e+00
13	13	14	-1.029e+00	-2.665e-03 -2.665e-03	-1.547e-01 8.007e-02	1.547e-01 0.000e+00	1.547e-01
14	14	15	-5.104e-01	-3.418e-01 -3.418e-01	-2.138e+00 -1.964e+00	2.138e+00 0.000e+00	2.138e+00
15	15	16	4.464e-02	-1.178e-02 -1.178e-02	-2.406e-01 -8.921e-02	2.406e-01 0.000e+00	2.406e-01

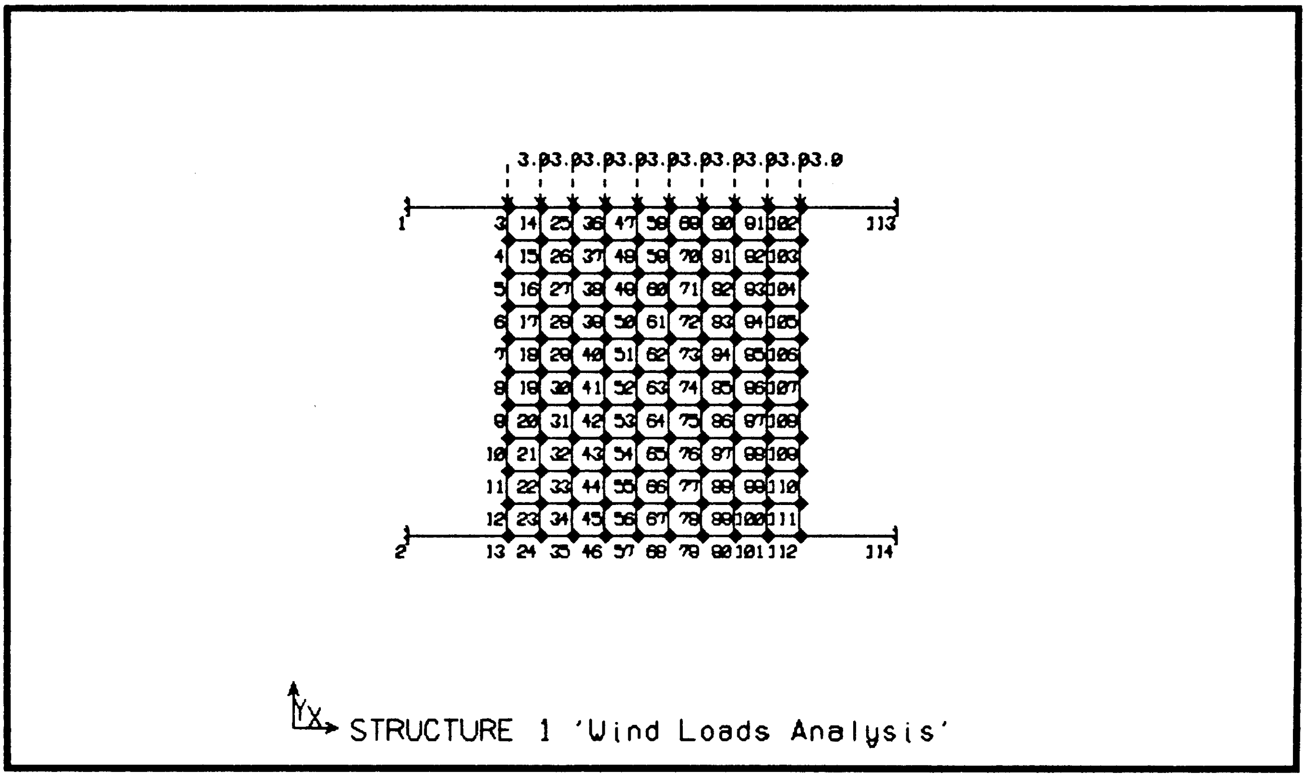
MEMBER	NODES		AXIAL_FORCE	START_SHEAR END_SHEAR	START_MOMENT END_MOMENT	MAX_MOMENT X_MAX	SPAN_MOMENT
16	16	17	8.387e-01	-5.044e-01 -5.044e-01	-3.062e+00 -2.992e+00	3.062e+00 0.000e+00	3.062e+00
17	17	18	1.729e+00	-3.903e-02 -3.903e-02	-5.496e-01 -5.433e-01	5.496e-01 0.000e+00	5.496e-01
18	18	19	2.896e+00	-6.762e-01 -6.762e-01	-4.059e+00 -4.056e+00	4.059e+00 0.000e+00	4.059e+00
19	19	20	4.349e+00	-1.571e+00 -1.571e+00	-3.142e+00 0.000e+00	3.142e+00 0.000e+00	3.142e+00
20	2	21	6.783e-01	-1.355e+00 -1.355e+00	-6.659e+00 -4.178e+00	6.659e+00 0.000e+00	6.659e+00
21	3	22	5.011e-01	-1.147e+00 -1.147e+00	-4.527e+00 -4.647e+00	-4.647e+00 8.000e+00	-4.647e+00
22	4	23	-6.340e-01	-9.316e-01 -9.316e-01	-3.705e+00 -3.748e+00	-3.748e+00 8.000e+00	-3.748e+00
23	5	24	3.179e-01	-8.155e-01 -8.155e-01	-3.237e+00 -3.287e+00	-3.287e+00 8.000e+00	-3.287e+00
24	6	25	-5.050e-01	-5.736e-01 -5.736e-01	-2.279e+00 -2.310e+00	-2.310e+00 8.000e+00	-2.310e+00
25	7	26	1.667e-01	-5.307e-01 -5.307e-01	-2.105e+00 -2.141e+00	-2.141e+00 8.000e+00	-2.141e+00
26	8	27	-3.443e-01	-2.760e-01 -2.760e-01	-1.097e+00 -1.111e+00	-1.111e+00 8.000e+00	-1.111e+00
27.	9	28	-2.019e-03	-2.592e-01 -2.592e-01	-1.027e+00 -1.047e+00	-1.047e+00 8.000e+00	-1.047e+00
28	10	29	-1.766e-01	-6.852e-03 -6.852e-03	-2.868e-02 -2.613e-02	2.868e-02 0.000e+00	2.868e-02
29	11	30	-1.729e-01	-1.659e-04 -1.659e-04	8.010e-04 -2.129e-03	-2.129e-03 8.000e+00	-2.129e-03
30	12	31	-5.770e-03	2.517e-01 2.517e-01	9.971e-01 1.017e+00	1.017e+00 8.000e+00	1.017e+00

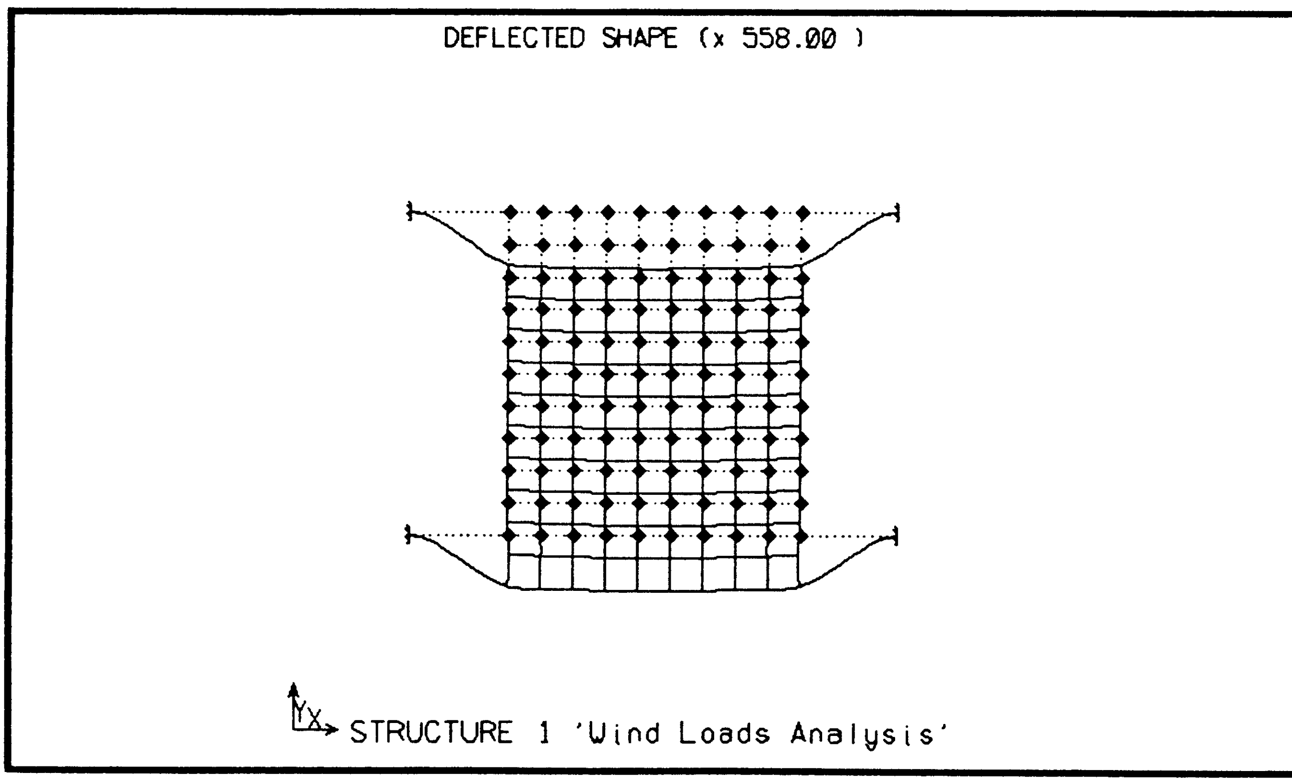
MEMBER	NODES		AXIAL_FORCE	START_SHEAR END_SHEAR	START_MOMENT END_MOMENT	MAX_MOMENT X_MAX	SPAN_MOMENT
31	13	32	-3.417e-01	2.656e-01 2.656e-01	1.055e+00 1.069e+00	1.069e+00 8.000e+00	1.069e+00
32	14	33	1.642e-01	5.189e-01 5.189e-01	2.058e+00 2.094e+00	2.094e+00 8.000e+00	2.094e+00
33	15	34	-5.050e-01	5.550e-01 5.550e-01	2.205e+00 2.236e+00	2.236e+00 8.000e+00	2.236e+00
34	16	35	3.177e-01	7.940e-01 7.940e-01	3.151e+00 3.201e+00	3.201e+00 8.000e+00	3.201e+00
35	17	36	-6.404e-01	8.908e-01 8.908e-01	3.541e+00 3.585e+00	3.585e+00 8.000e+00	3.585e+00
36	18	37	4.621e-01	1.167e+00 1.167e+00	4.602e+00 4.734e+00	4.734e+00 8.000e+00	4.734e+00
37	19	38	7.197e-01	1.452e+00 1.452e+00	7.197e+00 4.420e+00	-7.197e+00 0.000e+00	-7.197e+00
38	21	22	1.355e+00	6.783e-01 6.783e-01	4.178e+00 3.962e+00	-4.178e+00 0.000e+00	-4.178e+00
39	22	23	1.441e+00	4.801e-02 4.801e-02	6.851e-01 6.592e-01	-6.851e-01 0.000e+00	-6.851e-01
40	23	24	1.474e+00	5.198e-01 5.198e-01	3.089e+00 3.149e+00	3.149e+00 1.200e+01	3.149e+00
41	24	25	1.518e+00	1.471e-02 1.471e-02	1.384e-01 2.734e-01	2.734e-01 2.800e+01	2.734e-01
42	25	26	1.406e+00	3.536e-01 3.536e-01	2.037e+00 2.206e+00	2.206e+00 1.200e+01	2.206e+00
43	26	27	1.452e+00	3.453e-03 3.453e-03	-6.513e-02 1.618e-01	1.618e-01 2.800e+01	1.618e-01
44	27	28	1.307e+00	1.774e-01 1.774e-01	9.496e-01 1.179e+00	1.179e+00 1.200e+01	1.179e+00
45	28	29	1.402e+00	1.983e-04 1.983e-04	-1.320e-01 1.376e-01	1.376e-01 2.800e+01	1.376e-01

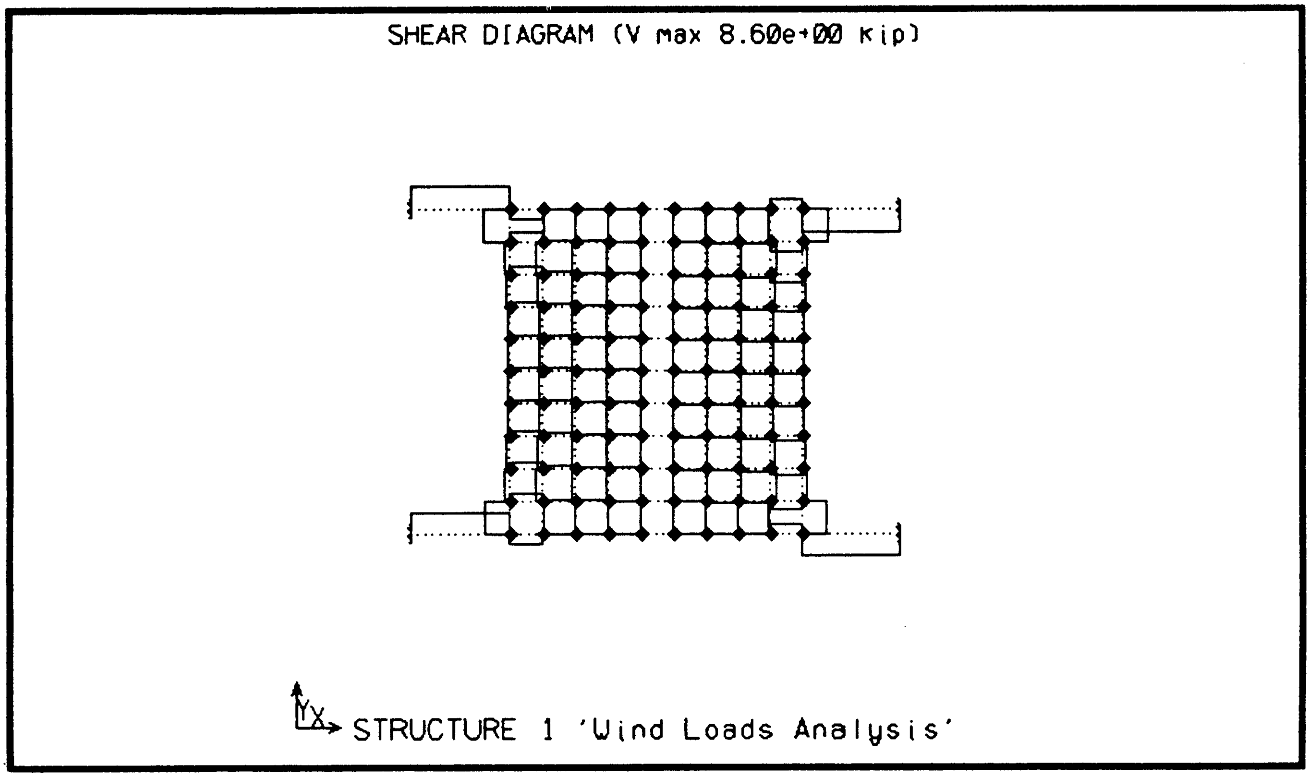
MEMBER	NODES		AXIAL_FORCE	START_SHEAR END_SHEAR	START_MOMENT END_MOMENT	MAX_MOMENT X_MAX	SPAN_MOMENT
46	29	30	1.264e+00	2.084e-03 2.084e-03	-1.114e-01 1.365e-01	1.365e-01 1.200e+01	1.365e-01
47	30	31	1.424e+00	1.249e-04 1.249e-04	-1.343e-01 1.378e-01	1.378e-01 2.800e+01	1.378e-01
48	31	32	1.309e+00	-1.732e-01 -1.732e-01	-1.154e+00 -9.241e-01	1.154e+00 0.000e+00	1.154e+00
49	32	33	1.524e+00	-1.972e-03 -1.972e-03	-1.453e-01 9.011e-02	1.453e-01 0.000e+00	1.453e-01
50	33	34	1.421e+00	-3.495e-01 -3.495e-01	-2.184e+00 -2.011e+00	2.184e+00 0.000e+00	2.184e+00
51	34	35	1.657e+00	-1.065e-02 -1.065e-02	-2.251e-01 -7.316e-02	2.251e-01 0.000e+00	2.251e-01
52	35	36	1.531e+00	-5.155e-01 -5.155e-01	-3.128e+00 -3.058e+00	3.128e+00 0.000e+00	3.128e+00
53	36	37	1.689e+00	-3.730e-02 -3.730e-02	-5.267e-01 -5.177e-01	5.267e-01 0.000e+00	5.267e-01
54	37	38	1.452e+00	-7.197e-01 -7.197e-01	-4.216e+00 -4.420e+00	-4.420e+00 1.200e+01	-4.420e+00
55	22	39	1.551e+00	0.000e+00 0.000e+00	0.000e+00 0.000e+00	0.000e+00 0.000e+00	0.000e+00
56	23	39	-1.425e+00	0.000e+00 0.000e+00	0.000e+00 0.000e+00	0.000e+00 0.000e+00	0.000e+00
57	24	40	1.128e+00	0.000e+00 0.000e+00	0.000e+00 0.000e+00	0.000e+00 0.000e+00	0.000e+00
58	25	40	-1.087e+00	0.000e+00 0.000e+00	0.000e+00 0.000e+00	0.000e+00 0.000e+00	0.000e+00
59	26	41	7.084e-01	0.000e+00 0.000e+00	0.000e+00 0.000e+00	0.000e+00 0.000e+00	0.000e+00
60	27	41	-6.677e-01	0.000e+00 0.000e+00	0.000e+00 0.000e+00	0.000e+00 0.000e+00	0.000e+00

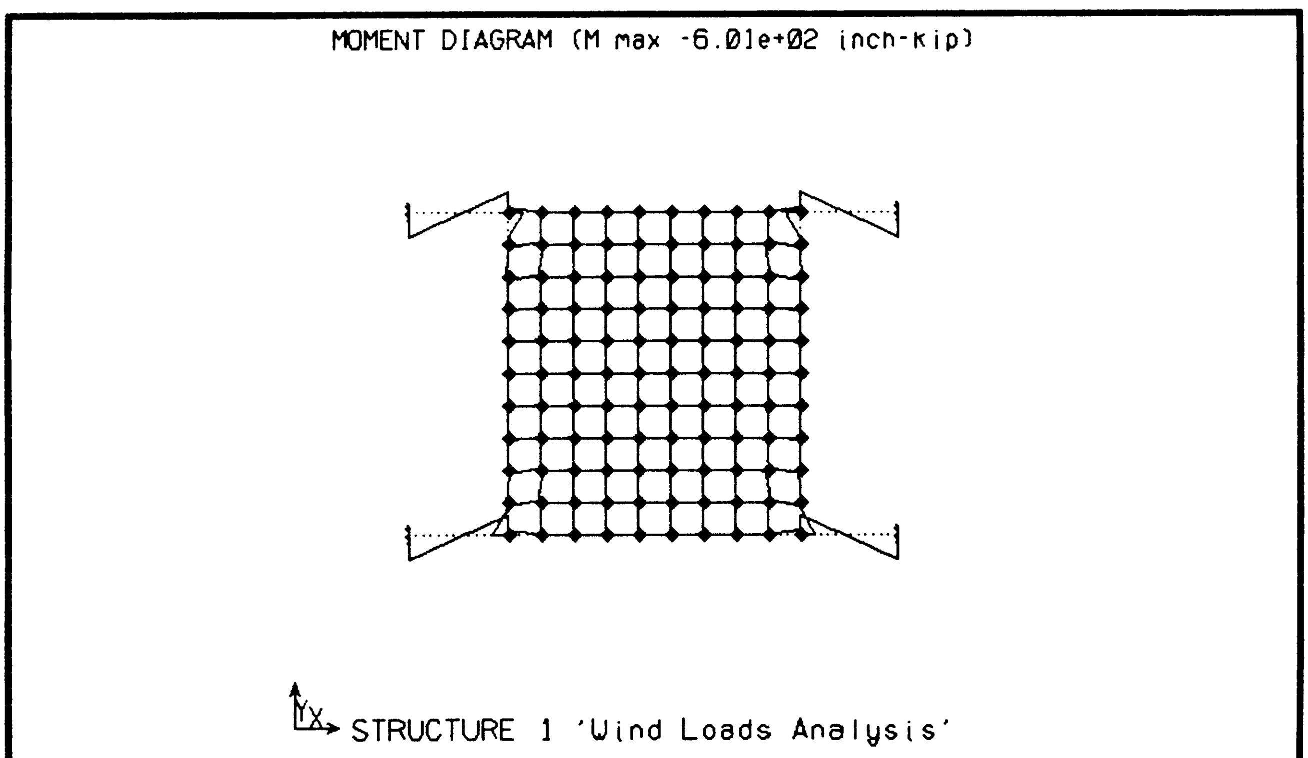
MEMBER	NODES		AXIAL_FORCE	START_SHEAR END_SHEAR	START_MOMENT END_MOMENT	MAX_MOMENT X_MAX	SPAN_MOMENT
61	28	42	2.401e-01	0.000e+00 0.000e+00	0.000e+00 0.000e+00	0.000e+00 0.000e+00	0.000e+00
62	29	42	-2.300e-01	0.000e+00 0.000e+00	0.000e+00 0.000e+00	0.000e+00 0.000e+00	0.000e+00
63	30	43	-2.343e-01	0.000e+00 0.000e+00	0.000e+00 0.000e+00	0.000e+00 0.000e+00	0.000e+00
64	31	43	2.159e-01	0.000e+00 0.000e+00	0.000e+00 0.000e+00	0.000e+00 0.000e+00	0.000e+00
65	32	44	-7.031e-01	0.000e+00 0.000e+00	0.000e+00 0.000e+00	0.000e+00 0.000e+00	0.000e+00
66	33	44	6.593e-01	0.000e+00 0.000e+00	0.000e+00 0.000e+00	0.000e+00 0.000e+00	0.000e+00
67	34	45	-1.157e+00	0.000e+00 0.000e+00	0.000e+00 0.000e+00	0.000e+00 0.000e+00	0.000e+00
68	35	45	1.060e+00	0.000e+00 0.000e+00	0.000e+00 0.000e+00	0.000e+00 0.000e+00	0.000e+00
69	36	46	-1.533e+00	0.000e+00 0.000e+00	0.000e+00 0.000e+00	0.000e+00 0.000e+00	0.000e+00
70	37	46	1.475e+00	0.000e+00 0.000e+00	0.000e+00 0.000e+00	0.000e+00 0.000e+00	0.000e+00
71	39	40	1.959e+00	2.559e-02 2.559e-02	0.000e+00 1.024e+00	1.024e+00 4.000e+01	1.024e+00
72	40	41	3.416e+00	4.740e-03 4.740e-03	-1.024e+00 1.213e+00	1.213e+00 4.000e+01	1.213e+00
73	41	42	4.322e+00	3.360e-03 3.360e-03	-1.213e+00 1.348e+00	1.348e+00 4.000e+01	1,348e+00
74	42	43	4.631e+00	1.730e-05 1.730e-05	-1.348e+00 1.348e+00	1.348e+00 4.000e+01	1.348e+00
75	43	44	4.335e+00	-3.315e-03 -3.315e-03	-1.348e+00 1.216e+00	1.348e+00 0.000e+00	1.348e+00

MEMBER	NODES		AXIAL_FORCE	START_SHEAR END_SHEAR	START_MOMENT END_MOMENT	MAX_MOMENT X_MAX	SPAN_MOMENT
76	44	45	3.438e+00	-4.506e-03 -4.506e-03	-1.216e+00 1.035e+00	1.216e+00 0.000e+00	1.216e+00
77	45	46	1.979e+00	-2.588e-02 -2.588e-02	-1.035e+00 0.000e+00	1.035e+00 0.000e+00	1.035e+00


STRUCTURE 1 'Wind Loads Analysis'


DEFLECTED SHAPE (x 558.00)
STRUCTURE 1 'Wind Loads Analysis'


SHEAR DIAGRAM (V max 8.60e+00 kip)
STRUCTURE 1 'Wind Loads Analysis'


MOMENT DIAGRAM (M max -6.01e+02 inch-kip)
STRUCTURE 1 'Wind Loads Analysis'

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MEMBER FORCES AND MOMENTS STRUCTURE 1 'Wind Loads Analysis
LOADING: CASE 1 2D UNITS: LENGTH (inch) FORCE (kip)

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MEMBER	NODES		AXIAL_FORCE	START_SHEAR END_SHEAR	START_MOMENT END_MOMENT	MAX_MOMENT X_MAX	SPAN_MOMENT
1	1	3	6.932e+00	7.564e+00 7.564e+00	6.007e+02 4.886e+02	-6.007e+02 0.000e+00	-6.007e+02
2	2	13	-6.765e+00	7.436e+00 7.436e+00	5.903e+02 4.805e+02	-5.903e+02 0.000e+00	-5.903e+02
3	102	113	6.932e+00	-7.564e+00 -7.564e+00	-4.886e+02 -6.007e+02	-6.007e+02 1.440e+02	-6.007e+02
4	112	114	-6.765e+00	-7.436e+00 -7.436e+00	-4.805e+02 -5.903e+02	-5.903e+02 1.440e+02	-5.903e+02
5	3	14	-1.672e+00	-3.112e+00 -3.112e+00	-1.338e+02 -1.560e+01	1.338e+02 0.000e+00	1.338e+02
6	14	25	-1.383e+00	1.179e-01 1.179e-01	3.904e+00 1.755e+00	-3.904e+00 0.000e+00	-3.904e+00
7	25	36	-1.262e+00	1.622e-02 1.622e-02	-2.229e+00 3.007e+00	3.007e+00 4.800e+01	3.007e+00
8	36	47	-1.264e+00	2.377e-02 2.377e-02	-1.850e+00 2.992e+00	2.992e+00 4.800e+01	2.992e+00
9	47	58	-1.273e+00	0.000e+00 0.000e+00	-2.416e+00 2.416e+00	2.416e+00 4.800e+01	2.416e+00
10	58	69	-1.264e+00	-2.377e-02 -2.377e-02	-2.992e+00 1.850e+00	2.992e+00 0.000e+00	2.992e+00
11	69	80	-1.262e+00	-1.622e-02 -1.622e-02	-3.007e+00 2.229e+00	3.007e+00 0.000e+00	3.007e+00
12	80	91	-1.383e+00	-1.179e-01 -1.179e-01	-1.755e+00 -3.904e+00	-3.904e+00 4.800e+01	-3.904e+00
13	91	102	-1.672e+00	3.112e+00 3.112e+00	1.560e+01 1.338e+02	1.338e+02 4.800e+01	1.338e+02
14	4	15	6.964e+00	3.141e+00 3.141e+00	9.030e+01 6.048e+01	-9.030e+01 0.000e+00	-9.030e+01
15	15	26	4.293e+00	2.971e-01 2.971e-01	9.843e-01 1.328e+01	1.328e+01 4.800e+01	1.328e+01

MEMBER	NODES		AXIAL_FORCE	START_SHEAR END_SHEAR	START_MOMENT END_MOMENT	MAX_MOMENT X_MAX	SPAN_MOMENT
16	26	37	3.058e+00	4.427e-01 4.427e-01	9.367e+00 1.188e+01	1.188e+01 4.800e+01	1.188e+01
17	37	48	2.430e+00	2.099e-01 2.099e-01	3.336e+00 6.738e+00	6.738e+00 4.800e+01	6.738e+00
18	48	59	2.236e+00	0.000e+00 0.000e+00	-1.683e+00 1.683e+00	1.683e+00 4.800e+01	1.683e+00
19	59	70	2.430e+00	-2.099e-01 -2.099e-01	-6.738e+00 -3.336e+00	6.738e+00 0.000e+00	6.738e+00
20	70	81	3.058e+00	-4.427e-01 -4.427e-01	-1.188e+01 -9.367e+00	1.188e+01 0.000e+00	1.188e+01
21	81	92	4.293e+00	-2.971e-01 -2.971e-01	-1.328e+01 -9.843e-01	1.328e+01 0.000e+00	1.328e+01
22	92	103	6.964e+00	-3.141e+00 -3.141e+00	-6.048e+01 -9.030e+01	-9.030e+01 4.800e+01	-9.030e+01
23	5	16	6.976e-01	2.501e+00 2.501e+00	6.513e+01 5.492e+01	-6.513e+01 0.000e+00	-6.513e+01
24	16	27	1.622e+00	1.309e+00 1.309e+00	3.043e+01 3.241e+01	3.241e+01 4.800e+01	3.241e+01
25	27	38	1.703e+00	7.781e-01 7.781e-01	1.759e+01 1.976e+01	1.976e+01 4.800e+01	1.976e+01
26	38	49	1.736e+00	3.911e-01 3.911e-01	8.452e+00 1.032e+01	1.032e+01 4.800e+01	1.032e+01
27	49	60	1.739e+00	0.000e+00 0.000e+00	-1.007e+00 1.007e+00	1.007e+00 4.800e+01	1.007e+00
28	60	71	1.736e+00	-3.911e-01 -3.911e-01	-1.032e+01 -8.452e+00	1.032e+01 0.000e+00	1.032e+01
29	71	82	1.703e+00	-7.781e-01 -7.781e-01	-1.976e+01 -1.759e+01	1.976e+01 0.000e+00	1.976e+01
30	82	93	1.622e+00	-1.309e+00 -1.309e+00	-3.241e+01 -3.043e+01	3.241e+01 0.000e+00	3.241e+01

MEMBER	NODES		AXIAL_FORCE	START_SHEAR END_SHEAR	START_MOMENT END_MOMENT	MAX_MOMENT X_MAX	SPAN_MOMENT
31	93	104	6.976e-01	-2.501e+00 -2.501e+00	-5.492e+01 -6.513e+01	-6.513e+01 4.800e+01	-6.513e+01
32	6	17	1.969e-01	1.662e+00 1.662e+00	4.351e+01 3.629e+01	-4.351e+01 0.000e+00	-4.351e+01
33	17	28	4.809e-01	1.182e+00 1.182e+00	2.726e+01 2.950e+01	2.950e+01 4.800e+01	2.950e+01
34	28	39	6.230e-01	7.433e-01 7.433e-01	1.665e+01 1.903e+01	1.903e+01 4.800e+01	1.903e+01
35	39	50	6.977e-01	3.705e-01 3.705e-01	7.820e+00 9.963e+00	9.963e+00 4.800e+01	9.963e+00
36	50	61	7.247e-01	0.000e+00 0.000e+00	-1.050e+00 1.050e+00	1.050e+00 4.800e+01	1.050e+00
37	61	72	6.977e-01	-3.705e-01 -3.705e-01	-9.963e+00 -7.820e+00	9.963e+00 0.000e+00	9.963e+00
38	72	83	6.230e-01	-7.433e-01 -7.433e-01	-1.903e+01 -1.665e+01	1.903e+01 0.000e+00	1.903e+01
39	83	94	4.809e-01	-1.182e+00 -1.182e+00	-2.950e+01 -2.726e+01	2.950e+01 0.000e+00	2.950e+01
40	94	105	1.969e-01	-1.662e+00 -1.662e+00	-3.629e+01 -4.351e+01	-4.351e+01 4.800e+01	-4.351e+01
41	7	18	7.776e-02	1.317e+00 1.317e+00	3.474e+01 2.847e+01	-3.474e+01 0.000e+00	-3.474e+01
42	18	29	1.822e-01	1.092e+00 1.092e+00	2.541e+01 2.702e+01	2.702e+01 4.800e+01	2.702e+01
43	29	40	2.165e-01	6.878e-01 6.878e-01	1.520e+01 1.781e+01	1.781e+01 4.800e+01	1.781e+01
44	40	51	2.367e-01	3.393e-01 3.393e-01	6.939e+00 9.349e+00	9.349e+00 4.800e+01	9.349e+00
45	51	62	2.443e-01	0.000e+00 0.000e+00	-1.177e+00 1.177e+00	1.177e+00 4.800e+01	1.177e+00

MEMBER	NODES		AXIAL_FORCE	START_SHEAR END_SHEAR	START_MOMENT END_MOMENT	MAX_MOMENT X_MAX	SPAN_MOMENT
46	62	73	2.367e-01	-3.393e-01	-9.349e+00	9.349e+00	9.349e+00
				-3.393e-01	-6.939e+00	0.000e+00	
47	73	84	2.165e-01	-6.878e-01	-1.781e+01	1.781e+01	1.781e+01
				-6.878e-01	-1.520e+01	0.000e+00	
48	84	95	1.822e-01	-1.092e+00	-2.702e+01	2.702e+01	2.702e+01
				-1.092e+00	-2.541e+01	0.000e+00	
49	95	106	7.776e-02	-1.317e+00	-2.847e+01	-3.474e+01	-3.474e+01
				-1.317e+00	-3.474e+01	4.800e+01	
50	8	19	4.552e-03	1.218e+00	3.224e+01	-3.224e+01	-3.224e+01
				1.218e+00	2.622e+01	0.000e+00	
51	19	30	1.061e-02	1.067e+00	2.490e+01	2.630e+01	2.630e+01
				1.067e+00	2.630e+01	4.800e+01	
52	30	41	1.368e-02	6.750e-01	1.489e+01	1.750e+01	1.750e+01
				6.750e-01	1.750e+01	4.800e+01	
53	41	52	1.467e-02	3.309e-01	6.700e+00	9.182e+00	9.182e+00
				3.309e-01	9.182e+00	4.800e+01	
54	52	63	1.489e-02	0.000e+00	-1.211e+00	1.211e+00	1.211e+00
				0.000e+00	1.211e+00	4.800e+01	
55	63	74	1.467e-02	-3.309e-01	-9.182e+00	9.182e+00	9.182e+00
				-3.309e-01	-6.700e+00	0.000e+00	
56	74	85	1.368e-02	-6.750e-01	-1.750e+01	1.750e+01	1.750e+01
				-6.750e-01	-1.489e+01	0.000e+00	
57	85	96	1.061e-02	-1.067e+00	-2.630e+01	2.630e+01	2.630e+01
				-1.067e+00	-2.490e+01	0.000e+00	
58	96	107	4.552e-03	-1.218e+00	-2.622e+01	-3.224e+01	-3.224e+01
				-1.218e+00	-3.224e+01	4.800e+01	
59	9	20	-6.792e-02	1.299e+00	3.428e+01	-3.428e+01	-3.428e+01
				1.299e+00	2.807e+01	0.000e+00	
60	20	31	-1.594e-01	1.083e+00	2.521e+01	2.678e+01	2.678e+01
				1.083e+00	2.678e+01	4.800e+01	

MEMBER	NODES		AXIAL_FORCE	START_SHEAR END_SHEAR	START_MOMENT END_MOMENT	MAX_MOMENT X_MAX	SPAN_MOMENT
61	31	42	-1.874e-01	6.849e-01	1.515e+01	1.773e+01	1.773e+01
				6.849e-01	1.773e+01	4.800e+01	
62	42	53	-2.055e-01	3.385e-01	6.923e+00	9.325e+00	9.325e+00
				3.385e-01	9.325e+00	4.800e+01	
63	53	64	-2.126e-01	0.000e+00	-1.176e+00	1.176e+00	1.176e+00
				0.000e+00	1.176e+00	4.800e+01	
64	64	75	-2.055e-01	-3.385e-01	-9.325e+00	9.325e+00	9.325e+00
				-3.385e-01	-6.923e+00	0.000e+00	
65	75	86	-1.874e-01	-6.849e-01	-1.773e+01	1.773e+01	1.773e+01
				-6.849e-01	-1.515e+01	0.000e+00	
66	86	97	-1.594e-01	-1.083e+00	-2.678e+01	2.678e+01	2.678e+01
				-1.083e+00	-2.521e+01	0.000e+00	
67	97	108	-6.792e-02	-1.299e+00	-2.807e+01	-3.428e+01	-3.428e+01
				-1.299e+00	-3.428e+01	4.800e+01	
68	10	21	-1.842e-01	1.622e+00	4.247e+01	-4.247e+01	-4.247e+01
				1.622e+00	3.539e+01	0.000e+00	
69	21	32	-4.522e-01	1.163e+00	2.685e+01	2.899e+01	2.899e+01
				1.163e+00	2.899e+01	4.800e+01	
70	32	43	-5.868e-01	7.371e-01	1.653e+01	1.885e+01	1.885e+01
				7.371e-01	1.885e+01	4.800e+01	
71	43	54	-6.588e-01	3.685e-01	7.779e+00	9.910e+00	9.910e+00
				3.685e-01	9.910e+00	4.800e+01	
72	54	65	-6.851e-01	0.000e+00	-1.049e+00	1.049e+00	1.049e+00
				0.000e+00	1.049e+00	4.800e+01	
73	65	76	-6.588e-01	-3.685e-01	-9.910e+00	9.910e+00	9.910e+00
				-3.685e-01	-7.779e+00	0.000e+00	
74	76	87	-5.868e-01	-7.371e-01	-1.885e+01	1.885e+01	1.885e+01
				-7.371e-01	-1.653e+01	0.000e+00	
75	87	98	-4.522e-01	-1.163e+00	-2.899e+01	2.899e+01	2.899e+01
				-1.163e+00	-2.685e+01	0.000e+00	

MEMBER	NODES		AXIAL_FORCE	START_SHEAR END_SHEAR	START_MOMENT END_MOMENT	MAX_MOMENT X_MAX	SPAN_MOMENT
76	98	109	-1.842e-01	-1.622e+00 -1.622e+00	-3.539e+01 -4.247e+01	-4.247e+01 4.800e+01	-4.247e+01
77	11	22	-6.738e-01	2.429e+00 2.429e+00	6.326e+01 5.330e+01	-6.326e+01 0.000e+00	-6.326e+01
78	22	33	-1.572e+00	1.282e+00 1.282e+00	2.984e+01 3.168e+01	3.168e+01 4.800e+01	3.168e+01
79	33	44	-1.648e+00	7.703e-01 7.703e-01	1.744e+01 1.953e+01	1.953e+01 4.800e+01	1.953e+01
80	44	55	-1.680e+00	3.888e-01 3.888e-01	8.404e+00 1.026e+01	1.026e+01 4.800e+01	1.026e+01
81	55	66	-1.683e+00	0.000e+00 0.000e+00	-1.003e+00 1.003e+00	1.003e+00 4.800e+01	1.003e+00
82	66	77	-1.680e+00	-3.888e-01 -3.888e-01	-1.026e+01 -8.404e+00	1.026e+01 0.000e+00	1.026e+01
83	77	88	-1.648e+00	-7.703e-01 -7.703e-01	-1.953e+01 -1.744e+01	1.953e+01 0.000e+00	1.953e+01
84	88	99	-1.572e+00	-1.282e+00 -1.282e+00	-3.168e+01 -2.984e+01	3.168e+01 0.000e+00	3.168e+01
85	99	110	-6.738e-01	-2.429e+00 -2.429e+00	-5.330e+01 -6.326e+01	-6.326e+01 4.800e+01	-6.326e+01
86	12	23	-6.831e+00	3.038e+00 3.038e+00	8.751e+01 5.831e+01	-8.751e+01 0.000e+00	-8.751e+01
87	23	34	-4.194e+00	2.856e-01 2.856e-01	9.024e-01 1.280e+01	1.280e+01 4.800e+01	1.280e+01
88	34	45	-2.984e+00	4.426e-01 4.426e-01	9.425e+00 1.182e+01	1.182e+01 4.800e+01	1.182e+01
89	45	56	-2.371e+00	2.115e-01 2.115e-01	3.405e+00 6.749e+00	6.749e+00 4.800e+01	6.749e+00
90	56	67	-2.181e+00	0.000e+00 0.000e+00	-1.662e+00 1.662e+00	1.662e+00 4.800e+01	1.662e+00

MEMBER	NODES		AXIAL_FORCE	START_SHEAR END_SHEAR	START_MOMENT END_MOMENT	MAX_MOMENT X_MAX	SPAN_MOMENT
91	67	78	-2.371e+00	-2.115e-01 -2.115e-01	-6.749e+00 -3.405e+00	6.749e+00 0.000e+00	6.749e+00
92	78	89	-2.984e+00	-4.426e-01 -4.426e-01	-1.182e+01 -9.425e+00	1.182e+01 0.000e+00	1.182e+01
93	89	100	-4.194e+00	-2.856e-01 -2.856e-01	-1.280e+01 -9.024e-01	1.280e+01 0.000e+00	1.280e+01
94	100	111	-6.831e+00	-3.038e+00 -3.038e+00	-5.831e+01 -8.751e+01	-8.751e+01 4.800e+01	-8.751e+01
95	13	24	1.655e+00	-3.116e+00 -3.116e+00	-1.329e+02 -1.664e+01	1.329e+02 0.000e+00	1.329e+02
96	24	35	1.338e+00	1.207e-01 1.207e-01	4.199e+00 1.592e+00	-4.199e+00 0.000e+00	-4.199e+00
97	35	46	1.221e+00	2.208e-02 2.208e-02	-1.997e+00 3.057e+00	3.057e+00 4.800e+01	3.057e+00
98	46	57	1.232e+00	2.715e-02 2.715e-02	-1.731e+00 3.034e+00	3.034e+00 4.800e+01	3.034e+00
99	57	68	1.243e+00	0.000e+00 0.000e+00	-2.389e+00 2.389e+00	2.389e+00 0.000e+00	2.389e+00
100	68	79	1.232e+00	-2.715e-02 -2.715e-02	-3.034e+00 1.731e+00	3.034e+00 0.000e+00	3.034e+00
101	79	90	1.221e+00	-2.208e-02 -2.208e-02	-3.057e+00 1.997e+00	3.057e+00 0.000e+00	3.057e+00
102	90	101	1.338e+00	-1.207e-01 -1.207e-01	-1.592e+00 -4.199e+00	-4.199e+00 4.800e+01	-4.199e+00
103	101	112	1.655e+00	3.116e+00 3.116e+00	1.664e+01 1.329e+02	1.329e+02 4.800e+01	1.329e+02
104	3	4	7.676e+00	-8.604e+00 -8.604e+00	-3.548e+02 -5.818e+01	3.548e+02 0.000e+00	3.548e+02
105	4	5	4.535e+00	-1.639e+00 -1.639e+00	-3.212e+01 -4.657e+01	-4.657e+01 4.800e+01	-4.657e+01

MEMBER	NODES		AXIAL_FORCE	START_SHEAR END_SHEAR	START_MOMENT END_MOMENT	MAX_MOMENT X_MAX	SPAN_MOMENT
106	5	6	2.034e+00	-9.417e-01 -9.417e-01	-1.856e+01 -2.664e+01	-2.664e+01 4.800e+01	-2.664e+01
107	6	7	3.713e-01	-7.448e-01 -7.448e-01	-1.686e+01 -1.889e+01	-1.889e+01 4.800e+01	-1.889e+01
108	7	8	-9.457e-01	-6.671e-01 -6.671e-01	-1.585e+01 -1.617e+01	-1.617e+01 4.800e+01	-1.617e+01
109	8	9	-2.164e+00	-6.625e-01 -6.625e-01	-1.608e+01 -1.572e+01	1.608e+01 0.000e+00	1.608e+01
110	9	10	-3.463e+00	-7.305e-01 -7.305e-01	-1.855e+01 -1.651e+01	1.855e+01 0.000e+00	1.855e+01
111	10	11	-5.085e+00	-9.147e-01 -9.147e-01	-2.596e+01 -1.794e+01	2.596e+01 0.000e+00	2.596e+01
112	11	12	-7.513e+00	-1.589e+00 -1.589e+00	-4.532e+01 -3.093e+01	4.532e+01 0.000e+00	4.532e+01
113	12	13	-1.055e+01	-8.419e+00 -8.419e+00	-5.659e+01 -3.475e+02	-3.475e+02 4.800e+01	-3.475e+02
114	14	15	-6.230e+00	2.884e-01 2.884e-01	1.170e+01 2.150e+00	-1.170e+01 0.000e+00	-1.170e+01
115	15	16	-3.385e+00	-2.383e+00 -2.383e+00	-6.362e+01 -5.075e+01	6.362e+01 0.000e+00	6.362e+01
116	16	17	-2.193e+00	-1.458e+00 -1.458e+00	-3.460e+01 -3.538e+01	-3.538e+01 4.800e+01	-3.538e+01
117	17	18	-1.713e+00	-1.174e+00 -1.174e+00	-2.817e+01 -2.817e+01	2.817e+01 0.000e+00	2.817e+01
118	18	19	-1.489e+00	-1.069e+00 -1.069e+00	-2.572e+01 -2.561e+01	2.572e+01 0.000e+00	2.572e+01
119	19	20	-1.338e+00	-1.063e+00 -1.063e+00	-2.551e+01 -2.553e+01	-2.553e+01 4.800e+01	-2.553e+01
120	20	21	-1.122e+00	-1.155e+00 -1.155e+00	-2.776e+01 -2.767e+01	2.776e+01 0.000e+00	2.776e+01

MEMBER	NODES		AXIAL_FORCE	START_SHEAR END_SHEAR	START_MOMENT END_MOMENT	MAX_MOMENT X_MAX	SPAN_MOMENT
121	21	22	-6.630e-01	-1.423e+00 -1.423e+00	-3.458e+01 -3.371e+01	3.458e+01 0.000e+00	3.458e+01
122	22	23	4.839e-01	-2.321e+00 -2.321e+00	-4.943e+01 -6.196e+01	-6.196e+01 4.800e+01	-6.196e+01
123	23	24	3.236e+00	3.163e-01 3.163e-01	2.742e+00 1.244e+01	1.244e+01 4.800e+01	1.244e+01
124	25	26	-2.898e+00	1.218e-01 1.218e-01	4.743e-01 5.370e+00	5.370e+00 4.800e+01	5.370e+00
125	26	27	-3.044e+00	-1.114e+00 -1.114e+00	-2.801e+01 -2.546e+01	2.801e+01 0.000e+00	2.801e+01
126	27	28	-2.513e+00	-1.033e+00 -1.033e+00	-2.454e+01 -2.507e+01	-2.507e+01 4.800e+01	-2.507e+01
127	28	29	-2.074e+00	-8.914e-01 -8.914e-01	-2.108e+01 -2.171e+01	-2.171e+01 4.800e+01	-2.171e+01
128	29	30	-1.669e+00	-8.571e-01 -8.571e-01	-2.052e+01 -2.062e+01	-2.062e+01 4.800e+01	-2.062e+01
129	30	31	-1.278e+00	-8.541e-01 -8.541e-01	-2.057e+01 -2.043e+01	2.057e+01 0.000e+00	2.057e+01
130	31	32	-8.793e-01	-8.821e-01 -8.821e-01	-2.150e+01 -2.084e+01	2.150e+01 0.000e+00	2.150e+01
131	32	33	-4.529e-01	-1.017e+00 -1.017e+00	-2.468e+01 -2.412e+01	2.468e+01 0.000e+00	2.468e+01
132	33	34	5.842e-02	-1.092e+00 -1.092e+00	-2.499e+01 -2.745e+01	-2.745e+01 4.800e+01	-2.745e+01
133	34	35	-9.858e-02	1.171e-01 1.171e-01	5.217e+00 4.049e-01	-5.217e+00 0.000e+00	-5.217e+00
134	36	37	-3.008e+00	-2.918e-03 -2.918e-03	-1.157e+00 1.017e+00	1.157e+00 0.000e+00	1.157e+00
135	37	38	-2.775e+00	-6.305e-01 -6.305e-01	-1.623e+01 -1.403e+01	1.623e+01 0.000e+00	1.623e+01

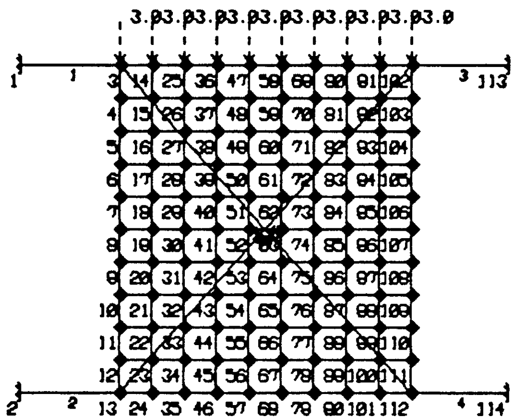
MEMBER	NODES		AXIAL_FORCE	START_SHEAR END_SHEAR	START_MOMENT END_MOMENT	MAX_MOMENT X_MAX	SPAN_MOMENT
136	38	39	-2.388e+00	-5.974e-01 -5.974e-01	-1.418e+01 -1.450e+01	-1.450e+01 4.800e+01	-1.450e+01
137	39	40	-2.015e+00	-5.227e-01 -5.227e-01	-1.235e+01 -1.274e+01	-1.274e+01 4.800e+01	-1.274e+01
138	40	41	-1.667e+00	-5.025e-01 -5.025e-01	-1.201e+01 -1.211e+01	-1.211e+01 4.800e+01	-1.211e+01
139	41	42	-1.322e+00	-5.015e-01 -5.015e-01	-1.209e+01 -1.198e+01	1.209e+01 0.000e+00	1.209e+01
140	42	43	-9.760e-01	-5.196e-01 -5.196e-01	-1.267e+01 -1.227e+01	1.267e+01 0.000e+00	1.267e+01
141	43	44	-6.075e-01	-5.916e-01 -5.916e-01	-1.436e+01 -1.404e+01	1.436e+01 0.000e+00	1.436e+01
142	44	45	-2.260e-01	-6.239e-01 -6.239e-01	-1.390e+01 -1.605e+01	-1.605e+01 4.800e+01	-1.605e+01
143	45	46	5.066e-03	-1.047e-02 -1.047e-02	8.238e-01 -1.326e+00	-1.326e+00 4.800e+01	-1.326e+00
144	47	48	-2.976e+00	-8.724e-03 -8.724e-03	-5.759e-01 1.572e-01	5.759e-01 0.000e+00	5.759e-01
145	48	49	-2.766e+00	-2.031e-01 -2.031e-01	-5.212e+00 -4.536e+00	5.212e+00 0.000e+00	5.212e+00
146	49	50	-2.375e+00	-2.001e-01 -2.001e-01	-4.780e+00 -4.823e+00	-4.823e+00 4.800e+01	-4.823e+00
147	50	51	-2.005e+00	-1.731e-01 -1.731e-01	-4.090e+00 -4.218e+00	-4.218e+00 4.800e+01	-4.218e+00
148	51	52	-1.665e+00	-1.655e-01 -1.655e-01	-3.954e+00 -3.988e+00	-3.988e+00 4.800e+01	-3.988e+00
149	52	53	-1.334e+00	-1.652e-01 -1.652e-01	-3.983e+00 -3.948e+00	3.983e+00 0.000e+00	3.983e+00
150	53	54	-9.960e-01	-1.724e-01 -1.724e-01	-4.200e+00 -4.073e+00	4.200e+00 0.000e+00	4.200e+00

MEMBER	NODES		AXIAL_FORCE	START_SHEAR END_SHEAR	START_MOMENT END_MOMENT	MAX_MOMENT X_MAX	SPAN_MOMENT
151	54	55	-6.275e-01	-1.986e-01 -1.986e-01	-4.789e+00 -4.743e+00	4.789e+00 0.000e+00	4.789e+00
152	55	56	-2.387e-01	-2.017e-01 -2.017e-01	-4.511e+00 -5.169e+00	-5.169e+00 4.800e+01	-5.169e+00
153	56	57	-2.715e-02	-1.172e-02 -1.172e-02	8.240e-02 -6.452e-01	-6.452e-01 4.800e+01	-6.452e-01
154	58	59	-2.976e+00	8.724e-03 8.724e-03	5.759e-01 -1.572e-01	-5.759e-01 0.000e+00	-5.759e-01
155	59	60	-2.766e+00	2.031e-01 2.031e-01	5.212e+00 4.536e+00	-5.212e+00 0.000e+00	-5.212e+00
156	60	61	-2.375e+00	2.001e-01 2.001e-01	4.780e+00 4.823e+00	4.823e+00 4.800e+01	4.823e+00
157	61	62	-2.005e+00	1.731e-01 1.731e-01	4.090e+00 4.218e+00	4.218e+00 4.800e+01	4.218e+00
158	62	63	-1.665e+00	1.655e-01 1.655e-01	3.954e+00 3.988e+00	3.988e+00 4.800e+01	3.988e+00
159	63	64	-1.334e+00	1.652e-01 1.652e-01	3.983e+00 3.948e+00	-3.983e+00 0.000e+00	-3.983e+00
160	64	65	-9.960e-01	1.724e-01 1.724e-01	4.200e+00 4.073e+00	-4.200e+00 0.000e+00	-4.200e+00
161	65	66	-6.275e-01	1.986e-01 1.986e-01	4.789e+00 4.743e+00	-4.789e+00 0.000e+00	-4.789e+00
162	66	67	-2.387e-01	2.017e-01 2.017e-01	4.511e+00 5.169e+00	5.169e+00 4.800e+01	5.169e+00
163	67	68	-2.715e-02	1.172e-02 1.172e-02	-8.240e-02 6.452e-01	6.452e-01 4.800e+01	6.452e-01
164	69	70	-3.008e+00	2.918e-03 2.918e-03	1.157e+00 -1.017e+00	-1.157e+00 0.000e+00	-1.157e+00
165	70	71	-2.775e+00	6.305e-01 6.305e-01	1.623e+01 1.403e+01	-1.623e+01 0.000e+00	-1.623e+01

MEMBER	NODES		AXIAL_FORCE	START_SHEAR END_SHEAR	START_MOMENT END_MOMENT	MAX_MOMENT X_MAX	SPAN_MOMENT
166	71	72	-2.388e+00	5.974e-01 5.974e-01	1.418e+01 1.450e+01	1.450e+01 4.800e+01	1.450e+01
167	72	73	-2.015e+00	5.227e-01 5.227e-01	1.235e+01 1.274e+01	1.274e+01 4.800e+01	1.274e+01
168	73	74	-1.667e+00	5.025e-01 5.025e-01	1.201e+01 1.211e+01	1.211e+01 4.800e+01	1.211e+01
169	74	75	-1.322e+00	5.015e-01 5.015e-01	1.209e+01 1.198e+01	-1.209e+01 0.000e+00	-1.209e+01
170	75	76	-9.760e-01	5.196e-01 5.196e-01	1.267e+01 1.227e+01	-1.267e+01 0.000e+00	-1.267e+01
171	76	77	-6.075e-01	5.916e-01 5.916e-01	1.436e+01 1.404e+01	-1.436e+01 0.000e+00	-1.436e+01
172	77	78	-2.260e-01	6.239e-01 6.239e-01	1.390e+01 1.605e+01	1.605e+01 4.800e+01	1.605e+01
173	78	79	5.066e-03	1.047e-02 1.047e-02	-8.238e-01 1.326e+00	1.326e+00 4.800e+01	1.326e+00
174	80	81	-2.898e+00	-1.218e-01 -1.218e-01	-4.743e-01 -5.370e+00	-5.370e+00 4.800e+01	-5.370e+00
175	81	82	-3.044e+00	1.114e+00 1.114e+00	2.801e+01 2.546e+01	-2.801e+01 0.000e+00	-2.801e+01
176	82	83	-2.513e+00	1.033e+00 1.033e+00	2.454e+01 2.507e+01	2.507e+01 4.800e+01	2.507e+01
177	83	84	-2.074e+00	8.914e-01 8.914e-01	2.108e+01 2.171e+01	2.171e+01 4.800e+01	2.171e+01
178	84	85	-1.669e+00	8.571e-01 8.571e-01	2.052e+01 2.062e+01	2.062e+01 4.800e+01	2.062e+01
179	85	86	-1.278e+00	8.541e-01 8.541e-01	2.057e+01 2.043e+01	-2.057e+01 0.000e+00	-2.057e+01
180	86	87	-8.793e-01	8.821e-01 8.821e-01	2.150e+01 2.084e+01	-2.150e+01 0.000e+00	-2.150e+01

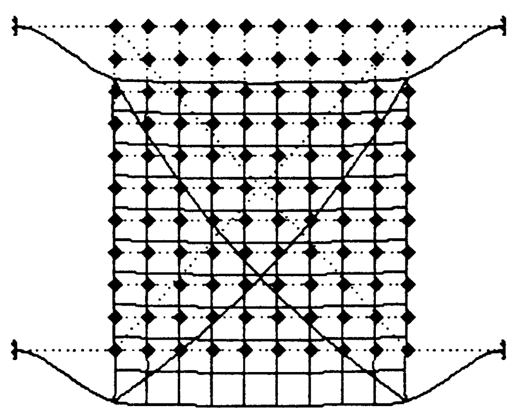
MEMBER	NODES		AXIAL_FORCE	START_SHEAR END_SHEAR	START_MOMENT END_MOMENT	MAX_MOMENT X_MAX	SPAN_MOMENT
181	87	88	-4.529e-01	1.017e+00 1.017e+00	2.468e+01 2.412e+01	-2.468e+01 0.000e+00	-2.468e+01
182	88	89	5.842e-02	1.092e+00 1.092e+00	2.499e+01 2.745e+01	2.745e+01 4.800e+01	2.745e+01
183	89	90	-9.858e-02	-1.171e-01 -1.171e-01	-5.217e+00 -4.049e-01	5.217e+00 0.000e+00	5.217e+00
184	91	92	-6.230e+00	-2.884e-01 -2.884e-01	-1.170e+01 -2.150e+00	1.170e+01 0.000e+00	1.170e+01
185	92	93	-3.385e+00	2.383e+00 2.383e+00	6.362e+01 5.075e+01	-6.362e+01 0.000e+00	-6.362e+01
186	93	94	-2.193e+00	1.458e+00 1.458e+00	3.460e+01 3.538e+01	3.538e+01 4.800e+01	3.538e+01
187	94	95	-1.713e+00	1.174e+00 1.174e+00	2.817e+01 2.817e+01	-2.817e+01 0.000e+00	-2.817e+01
188	95	96	-1.489e+00	1.069e+00 1.069e+00	2.572e+01 2.561e+01	-2.572e+01 0.000e+00	-2.572e+01
189	96	97	-1.338e+00	1.063e+00 1.063e+00	2.551e+01 2.553e+01	2.553e+01 4.800e+01	2.553e+01
190	97	98	-1.122e+00	1.155e+00 1.155e+00	2.776e+01 2.767e+01	-2.776e+01 0.000e+00	-2.776e+01
191	98	99	-6.630e-01	1.423e+00 1.423e+00	3.458e+01 3.371e+01	-3.458e+01 0.000e+00	-3.458e+01
192	99	100	4.839e-01	2.321e+00 2.321e+00	4.943e+01 6.196e+01	6.196e+01 4.800e+01	6.196e+01
193	100	101	3.236e+00	-3.163e-01 -3.163e-01	-2.742e+00 -1.244e+01	-1.244e+01 4.800e+01	-1.244e+01
194	102	103	7.676e+00	8.604e+00 8.604e+00	3.548e+02 5.818e+01	-3.548e+02 0.000e+00	-3.548e+02
195	103	104	4.535e+00	1.639e+00 1.639e+00	3.212e+01 4.657e+01	4.657e+01 4.800e+01	4.657e+01

MEMBER	NODES	AXIAL_FORCE	START_SHEAR END_SHEAR	START_MOMENT END_MOMENT	MAX_MOMENT X_MAX	SPAN_MOMENT
196	104 105	2.034e+00	9.417e-01 9.417e-01	1.856e+01 2.664e+01	2.664e+01 4.800e+01	2.664e+01
197	105 106	3.713e-01	7.448e-01 7.448e-01	1.686e+01 1.889e+01	1.889e+01 4.800e+01	1.889e+01
198	106 107	-9.457e-01	6.671e-01 6.671e-01	1.585e+01 1.617e+01	1.617e+01 4.800e+01	1.617e+01
199	107 108	-2.164e+00	6.625e-01 6.625e-01	1.608e+01 1.572e+01	-1.608e+01 0.000e+00	-1.608e+01
200	108 109	-3.463e+00	7.305e-01 7.305e-01	1.855e+01 1.651e+01	-1.855e+01 0.000e+00	-1.855e+01
201	109 110	-5.085e+00	9.147e-01 9.147e-01	2.596e+01 1.794e+01	-2.596e+01 0.000e+00	-2.596e+01
202	110 111	-7.513e+00	1.589e+00 1.589e+00	4.532e+01 3.093e+01	-4.532e+01 0.000e+00	-4.532e+01
203	111 112	-1.055e+01	8.419e+00 8.419e+00	5.659e+01 3.475e+02	3.475e+02 4.800e+01	3.475e+02

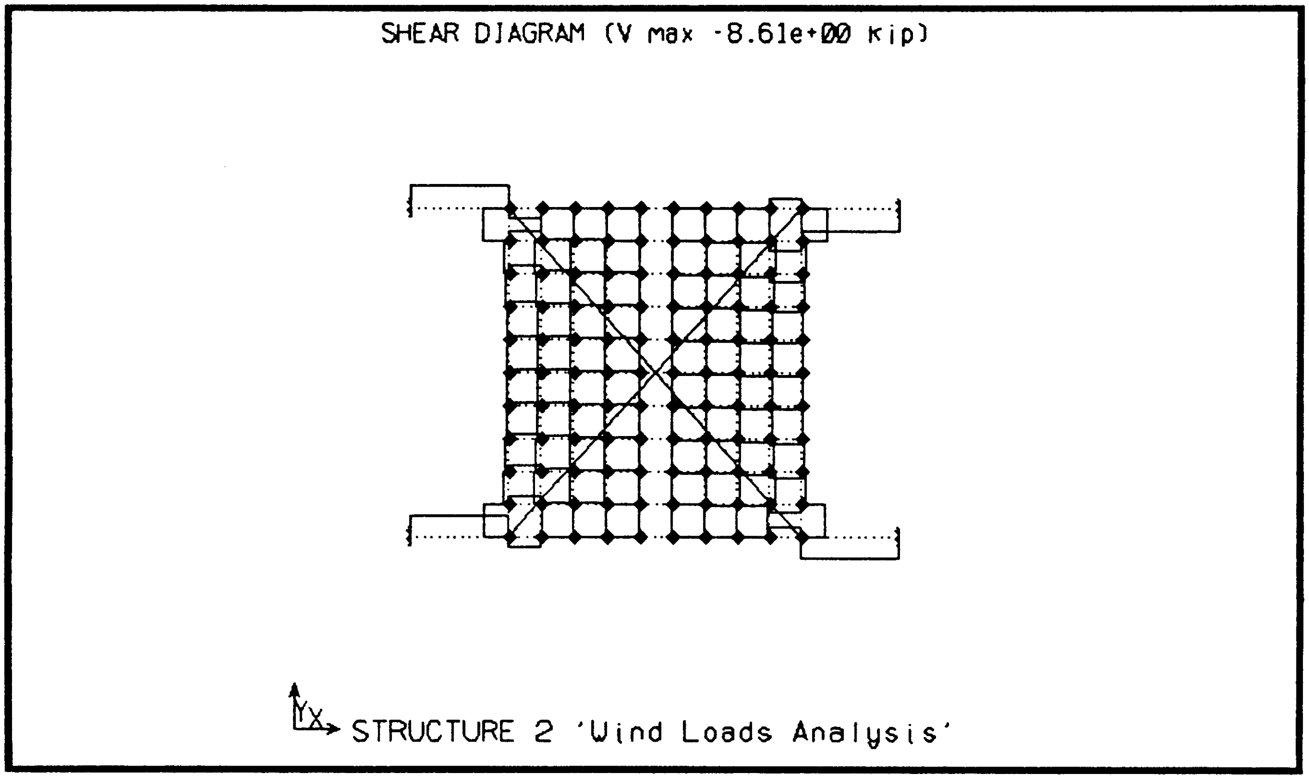


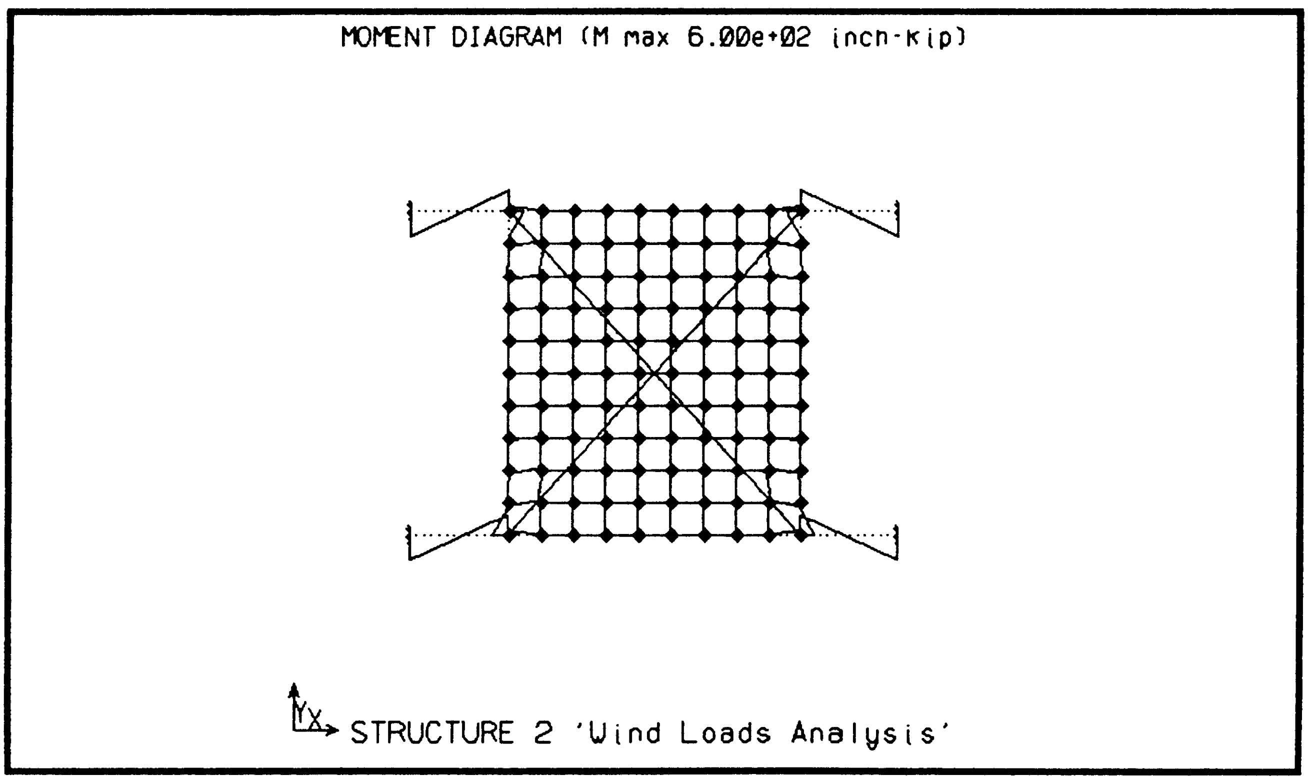
STRUCTURE 2 'Wind Loads Analysis'

DEFLECTED SHAPE (x 558.00)



STRUCTURE 2 'Wind Loads Analysis'


SHEAR DIAGRAM (V max -8.61e+00 kip)
STRUCTURE 2 'Wind Loads Analysis'


MOMENT DIAGRAM (M max 6.00e+02 inch-kip)
STRUCTURE 2 'Wind Loads Analysis'

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        MEMBER FORCES AND MOMENTS            STRUCTURE 2 'Wind Loads Analysis
        LOADING:         CASE 1        2D UNITS: LENGTH (inch)  FORCE (kip)

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MEMBER	NODES		AXIAL_FORCE	START_SHEAR END_SHEAR	START_MOMENT END_MOMENT	MAX_MOMENT X_MAX	SPAN_MOMENT
1	1	3	6.839e+00	7.559e+00 7.559e+00	6.003e+02 4.882e+02	-6.003e+02 0.000e+00	-6.003e+02
2	2	13	-6.856e+00	7.441e+00 7.441e+00	5.907e+02 4.809e+02	-5.907e+02 0.000e+00	-5.907e+02
3	102	113	6.839e+00	-7.559e+00 -7.559e+00	-4.882e+02 -6.003e+02	-6.003e+02 1.440e+02	-6.003e+02
4	112	114	-6.856e+00	-7.441e+00 -7.441e+00	-4.809e+02 -5.907e+02	-5.907e+02 1.440e+02	-5.907e+02
5	3	14	-1.636e+00	-3.087e+00 -3.087e+00	-1.331e+02 -1.511e+01	1.331e+02 0.000e+00	1.331e+02
6	14	25	-1.365e+00	1.204e-01 1.204e-01	3.893e+00 1.885e+00	-3.893e+00 0.000e+00	-3.893e+00
7	25	36	-1.249e+00	1.715e-02 1.715e-02	-2.223e+00 3.046e+00	3.046e+00 4.800e+01	3.046e+00
8	36	47	-1.253e+00	2.399e-02 2.399e-02	-1.851e+00 3.003e+00	3.003e+00 4.800e+01	3.003e+00
9	47	58	-1.262e+00	0.000e+00 0.000e+00	-2.419e+00 2.419e+00	2.419e+00 0.000e+00	2.419e+00
10	58	69	-1.253e+00	-2.399e-02 -2.399e-02	-3.003e+00 1.851e+00	3.003e+00 0.000e+00	3.003e+00
11	69	80	-1.249e+00	-1.715e-02 -1.715e-02	-3.046e+00 2.223e+00	3.046e+00 0.000e+00	3.046e+00
12	80	91	-1.365e+00	-1.204e-01 -1.204e-01	-1.885e+00 -3.893e+00	-3.893e+00 4.800e+01	-3.893e+00
13	91	102	-1.636e+00	3.087e+00 3.087e+00	1.511e+01 1.331e+02	1.331e+02 4.800e+01	1.331e+02
14	4	15	6.968e+00	3.160e+00 3.160e+00	9.077e+01 6.089e+01	-9.077e+01 0.000e+00	-9.077e+01
15	15	26	4.304e+00	3.051e-01 3.051e-01	1.161e+00 1.349e+01	1.349e+01 4.800e+01	1.349e+01

MEMBER	NODES		AXIAL_FORCE	START_SHEAR END_SHEAR	START_MOMENT END_MOMENT	MAX_MOMENT X_MAX	SPAN_MOMENT
16	26	37	3.069e+00	4.447e-01	9.403e+00	1.194e+01	1.194e+01
				4.447e-01	1.194e+01	4.800e+01	
17	37	48	2.441e+00	2.105e-01	3.348e+00	6.756e+00	6.756e+00
				2.105e-01	6.756e+00	4.800e+01	
18	48	59	2.247e+00	0.000e+00	-1.684e+00	1.684e+00	1.684e+00
				0.000e+00	1.684e+00	0.000e+00	
19	59	70	2.441e+00	-2.105e-01	-6.756e+00	6.756e+00	6.756e+00
				-2.105e-01	-3.348e+00	0.000e+00	
20	70	81	3.069e+00	-4.447e-01	-1.194e+01	1.194e+01	1.194e+01
				-4.447e-01	-9.403e+00	0.000e+00	
21	81	92	4.304e+00	-3.051e-01	-1.349e+01	1.349e+01	1.349e+01
				-3.051e-01	-1.161e+00	0.000e+00	
22	92	103	6.968e+00	-3.160e+00	-6.089e+01	-9.077e+01	-9.077e+01
				-3.160e+00	-9.077e+01	4.800e+01	
23	5	16	7.004e-01	2.512e+00	6.542e+01	-6.542e+01	-6.542e+01
				2.512e+00	5.517e+01	0.000e+00	
24	16	27	1.628e+00	1.315e+00	3.056e+01	3.257e+01	3.257e+01
				1.315e+00	3.257e+01	4.800e+01	
25	27	38	1.711e+00	7.801e-01	1.763e+01	1.981e+01	1.981e+01
				7.801e-01	1.981e+01	4.800e+01	
26	38	49	1.744e+00	3.917e-01	8.463e+00	1.034e+01	1.034e+01
				3.917e-01	1.034e+01	4.800e+01	
27	49	60	1.747e+00	0.000e+00	-1.008e+00	1.008e+00	1.008e+00
				0.000e+00	1.008e+00	0.000e+00	
28	60	71	1.744e+00	-3.917e-01	-1.034e+01	1.034e+01	1.034e+01
				-3.917e-01	-8.463e+00	0.000e+00	
29	71	82	1.711e+00	-7.801e-01	-1.981e+01	1.981e+01	1.981e+01
				-7.801e-01	-1.763e+01	0.000e+00	
30	82	93	1.628e+00	-1.315e+00	-3.257e+01	3.257e+01	3.257e+01
				-1.315e+00	-3.056e+01	0.000e+00	

MEMBER	NODES		AXIAL_FORCE	START_SHEAR END_SHEAR	START_MOMENT END_MOMENT	MAX_MOMENT X_MAX	SPAN_MOMENT
31	93	104	7.004e-01	-2.512e+00 -2.512e+00	-5.517e+01 -6.542e+01	-6.542e+01 4.800e+01	-6.542e+01
32	6	17	1.989e-01	1.669e+00 1.669e+00	4.368e+01 3.643e+01	-4.368e+01 0.000e+00	-4.368e+01
33	17	28	4.857e-01	1.186e+00 1.186e+00	2.735e+01 2.960e+01	2.960e+01 4.800e+01	2.960e+01
34	28	39	6.291e-01	7.446e-01 7.446e-01	1.668e+01 1.906e+01	1.906e+01 4.800e+01	1.906e+01
35	39	50	7.043e-01	3.709e-01 3.709e-01	7.826e+00 9.975e+00	9.975e+00 4.800e+01	9.975e+00
36	50	61	7.314e-01	0.000e+00 0.000e+00	-1.051e+00 1.051e+00	1.051e+00 0.000e+00	1.051e+00
37	61	72	7.043e-01	-3.709e-01 -3.709e-01	-9.975e+00 -7.826e+00	9.975e+00 0.000e+00	9.975e+00
38	72	83	6.291e-01	-7.446e-01 -7.446e-01	-1.906e+01 -1.668e+01	1.906e+01 0.000e+00	1.906e+01
39	83	94	4.857e-01	-1.186e+00 -1.186e+00	-2.960e+01 -2.735e+01	2.960e+01 0.000e+00	2.960e+01
40	94	105	1.989e-01	-1.669e+00 -1.669e+00	-3.643e+01 -4.368e+01	-4.368e+01 4.800e+01	-4.368e+01
41	7	18	7.948e-02	1.320e+00 1.320e+00	3.482e+01 2.854e+01	-3.482e+01 0.000e+00	-3.482e+01
42	18	29	1.863e-01	1.094e+00 1.094e+00	2.546e+01 2.707e+01	2.707e+01 4.800e+01	2.707e+01
43	29	40	2.219e-01	6.885e-01 6.885e-01	1.522e+01 1.783e+01	1.783e+01 4.800e+01	1.783e+01
44	40	51	2.426e-01	3.395e-01 3.395e-01	6.942e+00 9.355e+00	9.355e+00 4.800e+01	9.355e+00
45	51	62	2.503e-01	0.000e+00 0.000e+00	-1.178e+00 1.178e+00	1.178e+00 0.000e+00	1.178e+00

MEMBER	NODES		AXIAL_FORCE	START_SHEAR END_SHEAR	START_MOMENT END_MOMENT	MAX_MOMENT X_MAX	SPAN_MOMENT
46	62	73	2.426e-01	-3.395e-01 -3.395e-01	-9.355e+00 -6.942e+00	9.355e+00 0.000e+00	9.355e+00
47	73	84	2.219e-01	-6.885e-01 -6.885e-01	-1.783e+01 -1.522e+01	1.783e+01 0.000e+00	1.783e+01
48	84	95	1.863e-01	-1.094e+00 -1.094e+00	-2.707e+01 -2.546e+01	2.707e+01 0.000e+00	2.707e+01
49	95	106	7.948e-02	-1.320e+00 -1.320e+00	-2.854e+01 -3.482e+01	-3.482e+01 4.800e+01	-3.482e+01
50	8	19	6.167e-03	1.218e+00 1.218e+00	3.224e+01 2.622e+01	-3.224e+01 0.000e+00	-3.224e+01
51	19	30	1.452e-02	1.067e+00 1.067e+00	2.490e+01 2.630e+01	2.630e+01 4.800e+01	2.630e+01
52	30	41	1.892e-02	6.750e-01 6.750e-01	1.489e+01 1.750e+01	1.750e+01 4.800e+01	1.750e+01
53	41	52	2.040e-02	3.309e-01 3.309e-01	6.700e+00 9.182e+00	9.182e+00 4.800e+01	9.182e+00
54	52	63	2.073e-02	0.000e+00 0.000e+00	-1.211e+00 1.211e+00	1.211e+00 0.000e+00	1.211e+00
55	63	74	2.040e-02	-3.309e-01 -3.309e-01	-9.182e+00 -6.700e+00	9.182e+00 0.000e+00	9.182e+00
56	74	85	1.892e-02	-6.750e-01 -6.750e-01	-1.750e+01 -1.489e+01	1.750e+01 0.000e+00	1.750e+01
57	85	96	1.452e-02	-1.067e+00 -1.067e+00	-2.630e+01 -2.490e+01	2.630e+01 0.000e+00	2.630e+01
58	96	107	6.167e-03	-1.218e+00 -1.218e+00	-2.622e+01 -3.224e+01	-3.224e+01 4.800e+01	-3.224e+01
59	9	20	-6.619e-02	1.296e+00 1.296e+00	3.420e+01 2.800e+01	-3.420e+01 0.000e+00	-3.420e+01
60	20	31	-1.553e-01	1.081e+00 1.081e+00	2.517e+01 2.672e+01	2.672e+01 4.800e+01	2.672e+01

MEMBER	NODES		AXIAL_FORCE	START_SHEAR END_SHEAR	START_MOMENT END_MOMENT	MAX_MOMENT X_MAX	SPAN_MOMENT
61	31	42	-1.819e-01	6.842e-01 6.842e-01	1.513e+01 1.771e+01	1.771e+01 4.800e+01	1.771e+01
62	42	53	-1.996e-01	3.383e-01 3.383e-01	6.919e+00 9.319e+00	9.319e+00 4.800e+01	9.319e+00
63	53	64	-2.066e-01	0.000e+00 0.000e+00	-1.175e+00 1.175e+00	1.175e+00 0.000e+00	1.175e+00
64	64	75	-1.996e-01	-3.383e-01 -3.383e-01	-9.319e+00 -6.919e+00	9.319e+00 0.000e+00	9.319e+00
65	75	86	-1.819e-01	-6.842e-01 -6.842e-01	-1.771e+01 -1.513e+01	1.771e+01 0.000e+00	1.771e+01
66	86	97	-1.553e-01	-1.081e+00 -1.081e+00	-2.672e+01 -2.517e+01	2.672e+01 0.000e+00	2.672e+01
67	97	108	-6.619e-02	-1.296e+00 -1.296e+00	-2.800e+01 -3.420e+01	-3.420e+01 4.800e+01	-3.420e+01
68	10	21	-1.822e-01	1.615e+00 1.615e+00	4.230e+01 3.525e+01	-4.230e+01 0.000e+00	-4.230e+01
69	21	32	-4.473e-01	1.159e+00 1.159e+00	2.676e+01 2.889e+01	2.889e+01 4.800e+01	2.889e+01
70	32	43	-5.806e-01	7.358e-01 7.358e-01	1.650e+01 1.881e+01	1.881e+01 4.800e+01	1.881e+01
71	43	54	-6.521e-01	3.681e-01 3.681e-01	7.772e+00 9.899e+00	9.899e+00 4.800e+01	9.899e+00
72	54	65	-6.782e-01	0.000e+00 0.000e+00	-1.048e+00 1.048e+00	1.048e+00 0.000e+00	1.048e+00
73	65	76	-6.521e-01	-3.681e-01 -3.681e-01	-9.899e+00 -7.772e+00	9.899e+00 0.000e+00	9.899e+00
74	76	87	-5.806e-01	-7.358e-01 -7.358e-01	-1.881e+01 -1.650e+01	1.881e+01 0.000e+00	1.881e+01
75	87	98	-4.473e-01	-1.159e+00 -1.159e+00	-2.889e+01 -2.676e+01	2.889e+01 0.000e+00	2.889e+01

MEMBER	NODES		AXIAL_FORCE	START_SHEAR END_SHEAR	START_MOMENT END_MOMENT	MAX_MOMENT X_MAX	SPAN_MOMENT
76	98	109	-1.822e-01	-1.615e+00 -1.615e+00	-3.525e+01 -4.230e+01	-4.230e+01 4.800e+01	-4.230e+01
77	11	22	-6.708e-01	2.417e+00 2.417e+00	6.296e+01 5.305e+01	-6.296e+01 0.000e+00	-6.296e+01
78	22	33	-1.565e+00	1.275e+00 1.275e+00	2.971e+01 3.151e+01	3.151e+01 4.800e+01	3.151e+01
79	33	44	-1.639e+00	7.683e-01 7.683e-01	1.740e+01 1.947e+01	1.947e+01 4.800e+01	1.947e+01
80	44	55	-1.671e+00	3.882e-01 3.882e-01	8.393e+00 1.024e+01	1.024e+01 4.800e+01	1.024e+01
81	55	66	-1.674e+00	0.000e+00 0.000e+00	-1.002e+00 1.002e+00	1.002e+00 0.000e+00	1.002e+00
82	66	77	-1.671e+00	-3.882e-01 -3.882e-01	-1.024e+01 -8.393e+00	1.024e+01 0.000e+00	1.024e+01
83	77	88	-1.639e+00	-7.683e-01 -7.683e-01	-1.947e+01 -1.740e+01	1.947e+01 0.000e+00	1.947e+01
84	88	99	-1.565e+00	-1.275e+00 -1.275e+00	-3.151e+01 -2.971e+01	3.151e+01 0.000e+00	3.151e+01
85	99	110	-6.708e-01	-2.417e+00 -2.417e+00	-5.305e+01 -6.296e+01	-6.296e+01 4.800e+01	-6.296e+01
86	12	23	-6.826e+00	3.019e+00 3.019e+00	8.703e+01 5.789e+01	-8.703e+01 0.000e+00	-8.703e+01
87	23	34	-4.182e+00	2.777e-01 2.777e-01	7.320e-01 1.260e+01	1.260e+01 4.800e+01	1.260e+01
88	34	45	-2.972e+00	4.406e-01 4.406e-01	9.390e+00 1.176e+01	1.176e+01 4.800e+01	1.176e+01
89	45	56	-2.359e+00	2.109e-01 2.109e-01	3.395e+00 6.731e+00	6.731e+00 4.800e+01	6.731e+00
90	56	67	-2.169e+00	0.000e+00 0.000e+00	-1.660e+00 1.660e+00	1.660e+00 0.000e+00	1.660e+00

MEMBER	NODES		AXIAL_FORCE	START_SHEAR END_SHEAR	START_MOMENT END_MOMENT	MAX_MOMENT X_MAX	SPAN_MOMENT
91	67	78	-2.359e+00	-2.109e-01 -2.109e-01	-6.731e+00 -3.395e+00	6.731e+00 0.000e+00	6.731e+00
92	78	89	-2.972e+00	-4.406e-01 -4.406e-01	-1.176e+01 -9.390e+00	1.176e+01 0.000e+00	1.176e+01
93	89	100	-4.182e+00	-2.777e-01 -2.777e-01	-1.260e+01 -7.320e-01	1.260e+01 0.000e+00	1.260e+01
94	100	111	-6.826e+00	-3.019e+00 -3.019e+00	-5.789e+01 -8.703e+01	-8.703e+01 4.800e+01	-8.703e+01
95	13	24	1.689e+00	-3.139e+00 -3.139e+00	-1.336e+02 -1.711e+01	1.336e+02 0.000e+00	1.336e+02
96	24	35	1.356e+00	1.183e-01 1.183e-01	4.211e+00 1.465e+00	-4.211e+00 0.000e+00	-4.211e+00
97	35	46	1.234e+00	2.124e-02 2.124e-02	-2.001e+00 3.020e+00	3.020e+00 4.800e+01	3.020e+00
98	46	57	1.243e+00	2.696e-02 2.696e-02	-1.730e+00 3.024e+00	3.024e+00 4.800e+01	3.024e+00
99	57	68	1.254e+00	0.000e+00 0.000e+00	-2.386e+00 2.386e+00	2.386e+00 0.000e+00	2.386e+00
100	68	79	1.243e+00	-2.696e-02 -2.696e-02	-3.024e+00 1.730e+00	3.024e+00 0.000e+00	3.024e+00
101	79	90	1.234e+00	-2.124e-02 -2.124e-02	-3.020e+00 2.001e+00	3.020e+00 0.000e+00	3.020e+00
102	90	101	1.356e+00	-1.183e-01 -1.183e-01	-1.465e+00 -4.211e+00	-4.211e+00 4.800e+01	-4.211e+00
103	101	112	1.689e+00	3.139e+00 3.139e+00	1.711e+01 1.336e+02	1.336e+02 4.800e+01	1.336e+02
104	3	4	7.800e+00	-8.614e+00 -8.614e+00	-3.550e+02 -5.847e+01	3.550e+02 0.000e+00	3.550e+02
105	4	5	4.640e+00	-1.647e+00 -1.647e+00	-3.230e+01 -4.674e+01	-4.674e+01 4.800e+01	-4.674e+01

MEMBER	NODES		AXIAL_FORCE	START_SHEAR END_SHEAR	START_MOMENT END_MOMENT	MAX_MOMENT X_MAX	SPAN_MOMENT
106	5	6	2.128e+00	-9.463e-01 -9.463e-01	-1.867e+01 -2.675e+01	-2.675e+01 4.800e+01	-2.675e+01
107	6	7	4.592e-01	-7.473e-01 -7.473e-01	-1.693e+01 -1.894e+01	-1.894e+01 4.800e+01	-1.894e+01
108	7	8	-8.608e-01	-6.679e-01 -6.679e-01	-1.588e+01 -1.618e+01	-1.618e+01 4.800e+01	-1.618e+01
109	8	9	-2.079e+00	-6.617e-01 -6.617e-01	-1.606e+01 -1.570e+01	1.606e+01 0.000e+00	1.606e+01
110	9	10	-3.374e+00	-7.279e-01 -7.279e-01	-1.850e+01 -1.644e+01	1.850e+01 0.000e+00	1.850e+01
111	10	11	-4.990e+00	-9.100e-01 -9.100e-01	-2.585e+01 -1.783e+01	2.585e+01 0.000e+00	2.585e+01
112	11	12	-7.407e+00	-1.581e+00 -1.581e+00	-4.514e+01 -3.075e+01	4.514e+01 0.000e+00	4.514e+01
113	12	13	-1.043e+01	-8.406e+00 -8.406e+00	-5.628e+01 -3.472e+02	-3.472e+02 4.800e+01	-3.472e+02
114	14	15	-6.207e+00	2.711e-01 2.711e-01	1.122e+01 1.795e+00	-1.122e+01 0.000e+00	-1.122e+01
115	15	16	-3.353e+00	-2.392e+00 -2.392e+00	-6.385e+01 -5.097e+01	6.385e+01 0.000e+00	6.385e+01
116	16	17	-2.156e+00	-1.464e+00 -1.464e+00	-3.476e+01 -3.552e+01	-3.552e+01 4.800e+01	-3.552e+01
117	17	18	-1.673e+00	-1.177e+00 -1.177e+00	-2.826e+01 -2.825e+01	2.826e+01 0.000e+00	2.826e+01
118	18	19	-1.448e+00	-1.070e+00 -1.070e+00	-2.575e+01 -2.563e+01	2.575e+01 0.000e+00	2.575e+01
119	19	20	-1.296e+00	-1.062e+00 -1.062e+00	-2.549e+01 -2.549e+01	-2.549e+01 4.800e+01	-2.549e+01
120	20	21	-1.082e+00	-1.151e+00 -1.151e+00	-2.768e+01 -2.758e+01	2.768e+01 0.000e+00	2.768e+01

MEMBER	NODES		AXIAL_FORCE	START_SHEAR END_SHEAR	START_MOMENT END_MOMENT	MAX_MOMENT X_MAX	SPAN_MOMENT
121	21	22	-6.255e-01	-1.416e+00 -1.416e+00	-3.443e+01 -3.355e+01	3.443e+01 0.000e+00	3.443e+01
122	22	23	5.159e-01	-2.311e+00 -2.311e+00	-4.921e+01 -6.171e+01	-6.171e+01 4.800e+01	-6.171e+01
123	23	24	3.257e+00	3.332e-01 3.332e-01	3.089e+00 1.290e+01	1.290e+01 4.800e+01	1.290e+01
124	25	26	-2.897e+00	1.164e-01 1.164e-01	3.382e-01 5.248e+00	5.248e+00 4.800e+01	5.248e+00
125	26	27	-3.036e+00	-1.119e+00 -1.119e+00	-2.814e+01 -2.557e+01	2.814e+01 0.000e+00	2.814e+01
126	27	28	-2.501e+00	-1.037e+00 -1.037e+00	-2.462e+01 -2.514e+01	-2.514e+01 4.800e+01	-2.514e+01
127	28	29	-2.060e+00	-8.934e-01 -8.934e-01	-2.113e+01 -2.175e+01	-2.175e+01 4.800e+01	-2.175e+01
128	29	30	-1.654e+00	-8.578e-01 -8.578e-01	-2.054e+01 -2.064e+01	-2.064e+01 4.800e+01	-2.064e+01
129	30	31	-1.262e+00	-8.534e-01 -8.534e-01	-2.056e+01 -2.040e+01	2.056e+01 0.000e+00	2.056e+01
130	31	32	-8.650e-01	-8.801e-01 -8.801e-01	-2.145e+01 -2.079e+01	2.145e+01 0.000e+00	2.145e+01
131	32	33	-4.414e-01	-1.013e+00 -1.013e+00	-2.460e+01 -2.404e+01	2.460e+01 0.000e+00	2.460e+01
132	33	34	6.583e-02	-1.087e+00 -1.087e+00	-2.488e+01 -2.732e+01	-2.732e+01 4.800e+01	-2.732e+01
133	34	35	-9.702e-02	1.222e-01 1.222e-01	5.333e+00 5.354e-01	-5.333e+00 0.000e+00	-5.333e+00
134	36	37	-3.007e+00	-4.399e-03 -4.399e-03	-1.196e+00 9.844e-01	1.196e+00 0.000e+00	1.196e+00
135	37	38	-2.773e+00	-6.322e-01 -6.322e-01	-1.628e+01 -1.407e+01	1.628e+01 0.000e+00	1.628e+01

MEMBER	NODES		AXIAL_FORCE	START_SHEAR END_SHEAR	START_MOMENT END_MOMENT	MAX_MOMENT X_MAX	SPAN_MOMENT
136	38	39	-2.384e+00	-5.986e-01 -5.986e-01	-1.421e+01 -1.452e+01	-1.452e+01 4.800e+01	-1.452e+01
137	39	40	-2.010e+00	-5.234e-01 -5.234e-01	-1.237e+01 -1.276e+01	-1.276e+01 4.800e+01	-1.276e+01
138	40	41	-1.662e+00	-5.027e-01 -5.027e-01	-1.201e+01 -1.212e+01	-1.212e+01 4.800e+01	-1.212e+01
139	41	42	-1.317e+00	-5.012e-01 -5.012e-01	-1.209e+01 -1.197e+01	1.209e+01 0.000e+00	1.209e+01
140	42	43	-9.716e-01	-5.189e-01 -5.189e-01	-1.265e+01 -1.225e+01	1.265e+01 0.000e+00	1.265e+01
141	43	44	-6.040e-01	-5.904e-01 -5.904e-01	-1.433e+01 -1.401e+01	1.433e+01 0.000e+00	1.433e+01
142	44	45	-2.239e-01	-6.222e-01 -6.222e-01	-1.386e+01 -1.601e+01	-1.601e+01 4.800e+01	-1.601e+01
143	45	46	5.729e-03	-9.103e-03 -9.103e-03	8.534e-01 -1.290e+00	-1.290e+00 4.800e+01	-1.290e+00
144	47	48	-2.976e+00	-9.027e-03 -9.027e-03	-5.839e-01 1.506e-01	5.839e-01 0.000e+00	5.839e-01
145	48	49	-2.766e+00	-2.035e-01 -2.035e-01	-5.222e+00 -4.546e+00	5.222e+00 0.000e+00	5.222e+00
146	49	50	-2.374e+00	-2.003e-01 -2.003e-01	-4.786e+00 -4.829e+00	-4.829e+00 4.800e+01	-4.829e+00
147	50	51	-2.003e+00	-1.732e-01 -1.732e-01	-4.094e+00 -4.221e+00	-4.221e+00 4.800e+01	-4.221e+00
148	51	52	-1.663e+00	-1.655e-01 -1.655e-01	-3.956e+00 -3.989e+00	-3.989e+00 4.800e+01	-3.989e+00
149	52	53	-1.333e+00	-1.652e-01 -1.652e-01	-3.982e+00 -3.947e+00	3.982e+00 0.000e+00	3.982e+00
150	53	54	-9.942e-01	-1.722e-01 -1.722e-01	-4.197e+00 -4.069e+00	4.197e+00 0.000e+00	4.197e+00

MEMBER	NODES		AXIAL_FORCE	START_SHEAR END_SHEAR	START_MOMENT END_MOMENT	MAX_MOMENT X_MAX	SPAN_MOMENT
151	54	55	-6.261e-01	-1.983e-01 -1.983e-01	-4.782e+00 -4.737e+00	4.782e+00 0.000e+00	4.782e+00
152	55	56	-2.379e-01	-2.013e-01 -2.013e-01	-4.501e+00 -5.159e+00	-5.159e+00 4.800e+01	-5.159e+00
153	56	57	-2.696e-02	-1.146e-02 -1.146e-02	8.810e-02 -6.380e-01	-6.380e-01 4.800e+01	-6.380e-01
154	58	59	-2.976e+00	9.027e-03 9.027e-03	5.839e-01 -1.506e-01	-5.839e-01 0.000e+00	-5.839e-01
155	59	60	-2.766e+00	2.035e-01 2.035e-01	5.222e+00 4.546e+00	-5.222e+00 0.000e+00	-5.222e+00
156	60	61	-2.374e+00	2.003e-01 2.003e-01	4.786e+00 4.829e+00	4.829e+00 4.800e+01	4.829e+00
157	61	62	-2.003e+00	1.732e-01 1.732e-01	4.094e+00 4.221e+00	4.221e+00 4.800e+01	4.221e+00
158	62	63	-1.663e+00	1.655e-01 1.655e-01	3.956e+00 3.989e+00	3.989e+00 4.800e+01	3.989e+00
159	63	64	-1.333e+00	1.652e-01 1.652e-01	3.982e+00 3.947e+00	-3.982e+00 0.000e+00	-3.982e+00
160	64	65	-9.942e-01	1.722e-01 1.722e-01	4.197e+00 4.069e+00	-4.197e+00 0.000e+00	-4.197e+00
161	65	66	-6.261e-01	1.983e-01 1.983e-01	4.782e+00 4.737e+00	-4.782e+00 0.000e+00	-4.782e+00
162	66	67	-2.379e-01	2.013e-01 2.013e-01	4.501e+00 5.159e+00	5.159e+00 4.800e+01	5.159e+00
163	67	68	-2.696e-02	1.146e-02 1.146e-02	-8.810e-02 6.380e-01	6.380e-01 4.800e+01	6.380e-01
164	69	70	-3.007e+00	4.399e-03 4.399e-03	1.196e+00 -9.844e-01	-1.196e+00 0.000e+00	-1.196e+00
165	70	71	-2.773e+00	6.322e-01 6.322e-01	1.628e+01 1.407e+01	-1.628e+01 0.000e+00	-1.628e+01

MEMBER	NODES		AXIAL_FORCE	START_SHEAR END_SHEAR	START_MOMENT END_MOMENT	MAX_MOMENT X_MAX	SPAN_MOMENT
166	71	72	-2.384e+00	5.986e-01 5.986e-01	1.421e+01 1.452e+01	1.452e+01 4.800e+01	1.452e+01
167	72	73	-2.010e+00	5.234e-01 5.234e-01	1.237e+01 1.276e+01	1.276e+01 4.800e+01	1.276e+01
168	73	74	-1.662e+00	5.027e-01 5.027e-01	1.201e+01 1.212e+01	1.212e+01 4.800e+01	1.212e+01
169	74	75	-1.317e+00	5.012e-01 5.012e-01	1.209e+01 1.197e+01	-1.209e+01 0.000e+00	-1.209e+01
170	75	76	-9.716e-01	5.189e-01 5.189e-01	1.265e+01 1.225e+01	-1.265e+01 0.000e+00	-1.265e+01
171	76	77	-6.040e-01	5.904e-01 5.904e-01	1.433e+01 1.401e+01	-1.433e+01 0.000e+00	-1.433e+01
172	77	78	-2.239e-01	6.222e-01 6.222e-01	1.386e+01 1.601e+01	1.601e+01 4.800e+01	1.601e+01
173	78	79	5.729e-03	9.103e-03 9.103e-03	-8.534e-01 1.290e+00	1.290e+00 4.800e+01	1.290e+00
174	80	81	-2.897e+00	-1.164e-01 -1.164e-01	-3.382e-01 -5.248e+00	-5.248e+00 4.800e+01	-5.248e+00
175	81	82	-3.036e+00	1.119e+00 1.119e+00	2.814e+01 2.557e+01	-2.814e+01 0.000e+00	-2.814e+01
176	82	83	-2.501e+00	1.037e+00 1.037e+00	2.462e+01 2.514e+01	2.514e+01 4.800e+01	2.514e+01
177	83	84	-2.060e+00	8.934e-01 8.934e-01	2.113e+01 2.175e+01	2.175e+01 4.800e+01	2.175e+01
178	84	85	-1.654e+00	8.578e-01 8.578e-01	2.054e+01 2.064e+01	2.064e+01 4.800e+01	2.064e+01
179	85	86	-1.262e+00	8.534e-01 8.534e-01	2.056e+01 2.040e+01	-2.056e+01 0.000e+00	-2.056e+01
180	86	87	-8.650e-01	8.801e-01 8.801e-01	2.145e+01 2.079e+01	-2.145e+01 0.000e+00	-2.145e+01

MEMBER	NODES		AXIAL_FORCE	START_SHEAR END_SHEAR	START_MOMENT END_MOMENT	MAX_MOMENT X_MAX	SPAN_MOMENT
181	87	88	-4.414e-01	1.013e+00 1.013e+00	2.460e+01 2.404e+01	-2.460e+01 0.000e+00	-2.460e+01
182	88	89	6.583e-02	1.087e+00 1.087e+00	2.488e+01 2.732e+01	2.732e+01 4.800e+01	2.732e+01
183	89	90	-9.702e-02	-1.222e-01 -1.222e-01	-5.333e+00 -5.354e-01	5.333e+00 0.000e+00	5.333e+00
184	91	92	-6.207e+00	-2.711e-01 -2.711e-01	-1.122e+01 -1.795e+00	1.122e+01 0.000e+00	1.122e+01
185	92	93	-3.353e+00	2.392e+00 2.392e+00	6.385e+01 5.097e+01	-6.385e+01 0.000e+00	-6.385e+01
186	93	94	-2.156e+00	1.464e+00 1.464e+00	3.476e+01 3.552e+01	3.552e+01 4.800e+01	3.552e+01
187	94	95	-1.673e+00	1.177e+00 1.177e+00	2.826e+01 2.825e+01	-2.826e+01 0.000e+00	-2.826e+01
188	95	96	-1.448e+00	1.070e+00 1.070e+00	2.575e+01 2.563e+01	-2.575e+01 0.000e+00	-2.575e+01
189	96	97	-1.296e+00	1.062e+00 1.062e+00	2.549e+01 2.549e+01	2.549e+01 4.800e+01	2.549e+01
190	97	98	-1.082e+00	1.151e+00 1.151e+00	2.768e+01 2.758e+01	-2.768e+01 0.000e+00	-2.768e+01
191	98	99	-6.255e-01	1.416e+00 1.416e+00	3.443e+01 3.355e+01	-3.443e+01 0.000e+00	-3.443e+01
192	99	100	5.159e-01	2.311e+00 2.311e+00	4.921e+01 6.171e+01	6.171e+01 4.800e+01	6.171e+01
193	100	101	3.257e+00	-3.332e-01 -3.332e-01	-3.089e+00 -1.290e+01	-1.290e+01 4.800e+01	-1.290e+01
194	102	103	7.800e+00	8.614e+00 8.614e+00	3.550e+02 5.847e+01	-3.550e+02 0.000e+00	-3.550e+02
195	103	104	4.640e+00	1.647e+00 1.647e+00	3.230e+01 4.674e+01	4.674e+01 4.800e+01	4.674e+01

MEMBER	NODES	AXIAL_FORCE	START_SHEAR END_SHEAR	START_MOMENT END_MOMENT	MAX_MOMENT X_MAX	SPAN_MOMENT
196	104 105	2.128e+00	9.463e-01 9.463e-01	1.867e+01 2.675e+01	2.675e+01 4.800e+01	2.675e+01
197	105 106	4.592e-01	7.473e-01 7.473e-01	1.693e+01 1.894e+01	1.894e+01 4.800e+01	1.894e+01
198	106 107	-8.608e-01	6.679e-01 6.679e-01	1.588e+01 1.618e+01	1.618e+01 4.800e+01	1.618e+01
199	107 108	-2.079e+00	6.617e-01 6.617e-01	1.606e+01 1.570e+01	-1.606e+01 0.000e+00	-1.606e+01
200	108 109	-3.374e+00	7.279e-01 7.279e-01	1.850e+01 1.644e+01	-1.850e+01 0.000e+00	-1.850e+01
201	109 110	-4.990e+00	9.100e-01 9.100e-01	2.585e+01 1.783e+01	-2.585e+01 0.000e+00	-2.585e+01
202	110 111	-7.407e+00	1.581e+00 1.581e+00	4.514e+01 3.075e+01	-4.514e+01 0.000e+00	-4.514e+01
203	111 112	-1.043e+01	8.406e+00 8.406e+00	5.628e+01 3.472e+02	3.472e+02 4.800e+01	3.472e+02
204	3 112	-2.079e-01	-1.277e-05 -1.277e-05	-9.229e-02 8.405e-02	9.229e-02 0.000e+00	9.229e-02
205	13 102	-2.079e-01	1.277e-05	-8.405e-02	9.229e-02	9.229e-02

References

1/ Architectural Technology, *Wired for Change, Pg. 14-26,* by Gary Hall - Spring, 1984.

2/ Ashrae Handbook - 1985 Fundamentals, *Chapter 32, Section 32.16 & 32.2,* by American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.

3/ Advances in Tall Buildings, *Handing the Energy Impact of the Electronic "Office of the Future", Pg. 209- 221,* by Lynn S. Beedle.

4/ Architectural Technology, *Smart Buildings, Pg. 21-35,* by Bea Sennewald - March/April, 1986.

5/ Intelligent Buildings, *Chapter 5, Intelligent Building Information Systems, Pg. 75 - 104,* by Michelle D. Gouin and Thomas B. Cross - 1986.

6/ Building Services, *Communications, Pg. 33-40,* by Archie Spence and John Davy - September, 1985.

7/ Intelligent Buildings, *Chapter 8, The Impact of Information Technology on Building and People, pg. 137-138,* by Michelle D. Gouin and Thomas B. Cross - 1986.

Bibliography

Acier/Stahl/Steel, Sept 65, *A composite Floor-Ceiling Construction*, by J. P. Lacroix.

Acier/Stahl/Steel, June 74, *Present Trends in Multi-Storey Building Construction*, by Dr.-ing. Sontag.

Acier/Stahl/Steel, Jan 76, *The Wind-Bracing of Steel-Framed Multi-Storey Buildings*, by Andrea G. Bolocan.

Acier/Stahl/Steel, April 77, *Exhibition Halls for the Verona Fair (Italy)*, by Dott. ing. Ignazio Scola.

Acier/Stahl/Steel, March 78, *Industrial Complex (Algeria)*, by Jean Lafitte.

Advances in Tall Buildings, *Systems and Concepts; Criteria and Loading*, by Lynn S. Beedle.

Air Distribution Systems Report, *Ceiling-Mounted Outlets, Floor-Mounted Outlets & Desk Outlets*, by Designed for Sound Ltd..

Architectural Graphic Standards, *Open Web Steel Joists, Access Floors, Ceiling Suspension Systems*, edited by Robert T. Packard, AIA.

Architectural Record, Nov 86, *Lloyd,s of London*, by Deborah K. Dietsch.

Architectural Review, April 86, *Special Issue on the Hong Kong and Shanghai Bank*, Hong Kong , by Sean Mulcahy.

Architectural Review, Feb 87, *Products Survey*, by Ken Shuttleworth.

Architectural Technology, Spring 84, *Wired for Change*, by Gary Hall.

Architectural Technology, March/April 86, *Smart Buildings: Facts, Myths and Implications*, by Bea Sennewald.

Architectural Technology, July/August 86, *Indoor Air At Issue*, by James B. Gardner.

Ashrae Journal, July 86, *A Floor-Based Approach*, by Derek Tuddenham.

Ashrae Handbook, 1985 Fundamentals, *Space Air Diffusion, Duct Design, Pipe Sizing &*

Return and Exhaust Inlets, by A.S.H.R.A.E..

Building Design & Construction, Nov 86, *Clean Room Design Demands Specialized Systems*, by E. Michael Stanley and Ben Brooks.

Building Services, Nov 83, *Fire Protection of Cable Runs*, by W. R. Mesley.

Building Services, Jan 85, *Air Handling*, by Paul Appleby.

Building Services, Sept 85, *Spinning the Web*, by Archie Spence and John Davy; *The Best Way In*, by Paul Whittle and Chris Walls.

Building Services, Nov 86, *Low Level Supply: Application and Design*, by Paul Appleby.

Civil Engineering, March 85, *Developments in Multi-Storey Buildings*, by R. B. Haryott.

Civil Engineering, Nov/Dec 85, *Design for Fire - the Future Challenge*, by Jeff Robinson.

Civil Engineering, May 86, *Fire Protection for Structural Steel*, by David Shenton.

Civil Engineering, Oct 86, *Multi-Storey Construction - Trends Turn to Steel,* by Dr Colin Billington & Dr Bob Latter; *Pedestral Flooring for Lloyd's*, edited by Colin Degerlund.

Cold-formed Steel Design, *Corrugated Sheets; Composite Design,* by Wei- Wen Yu.

Concepts in Building Firesafety, *Building Materials and Constructions; Fire Detection and Suppression,* by M. David Egan.

Concrete International, April 80, *Certain Details of Tilt-Up Wall Panel Construction*, by Steven A. McKinney.

Concrete International, June 86, *Rigging the Tilt-Up*, by David L. Kelly.

Construction Sealants and Adhesives, *Preformed Gasket Seals,* by John Philip. Cook & Julian R. Panek.

Consulting Engineer, April 84, *HVAC Systems for New-Generation R & D Labs*, by Gordon R. Desmond, Jr..

Consulting Engineer, Dec 86, *New Directions in Hospital Design*, by Vincent A. Megna, P.E., Marin I. Sabic, AIA & Norman A. Brady.

Design and Operation of Clean Rooms, *Down-Flow Room Design*, by Philip R. Austin.

Design Fire Protection for Steel Truss, Second Edition, *Building Code Requirements and*

Design Concepts, by American Iron and Steel Institute.

Design of Steel Structures, *General Principles of Structural Design,* by Boris Bresler & T. Y. Lin.

Design of Welded Structures, *Open-Web Expanded Beams and Girders*, by Omer W. Blodgett.

Designing the Automated Office, *Space Planning and Design; Selecting/ Specifying Furnishings and Equipment,* by William L. Pulgram & Richard E. Stonis.

Engineering News Record, Oct 4, 84, *Daring Design is Quest for 'Best'*, by McGraw Hill Publisher.

Engineering Journal, Second Quarter, 76, *Design Example for Beams with Web Openings,* by Richard L. Kussman and Peter B. Cooper.

Fastener Data Book, *Locking Cap Screws in tapped holes,* by Industrial Fasteners Institute.

Fasteners Handbook, *Screws, Bolts, and Studs; Nuts,* by Julius Soled, P.E..

Fiber Optics, *Fiber-Optic Geometry & Typical Optical Fibers and Cables and Their Installation,* by Robert G. Seippel.

Fires in Buildings, *Costs and Benefits of Fire Protection,* by R. Mourareau & M. Thomas.

Fires in High-Rise Buildings, *A Life Safety Sprinkler System; Automatic Sprinkler Experience in High-Rise Buildings,* by N.F.P.A..

Fire Journal, July 83, *The Technology of Infrared and Ultraviolet Detection*, by Ron Hemond and Roger Wendt.

Fire Journal, Sept 83, *Toxicity of Combustion Products: Current Knowledge*, by Frederic B. Clarke, III.

Fire Journal, Nov 85, *Fire Tests and Fire-Resistant Telecommunications Cables,* by Stanley Kaufman.

Fire Protection Handbook, Fifth Edition, *Standard for the Protection of Electronic Computer/Data Processing Equipment, Standard Method of Test for Fire and Smoke Characteristics of Wires and Cables & Fire Protection of Structural Steel*, by National

Fire Protection Association.

Fire-Resistant Steel-Frame Construction, Second Edition, *Fire Protection Materials, Fire Protection Methods, Steel at Elevated Temperatures - Structural Properties & Fire Resistance Ratings*, by American Iron and Steel Institute.

Flame Retardant Needs of the Future, *Wire and Cable for the Plenum: A Challenge to I ndustry,* by Fire Retardant Chemical Association.

FOC/LAN 84, *Designing Fiber Optic Cables for Installation in Buildings*, by T. M. Williamson.

Fundamentals of Building Construction - Materials & Methods, *Steel Frame Construction*, by Edward Allen.

Heating/Piping/Air Conditioning, Nov 85, *Duct Hanger Locations*, by John Habjan.

Heating/Piping/Air Conditioning, Dec 85, *Duct Hanger Location Guidelines*, by John Habjan.

Heating/Piping/Air Conditioning, May 86, *Clean Rooms and Air Conditioning*, by Laszlo G. Kutas, P.E..

High-Rise Buildings Structures, *The Floor Structure or Horizontal Building Plane,* by Wolfgang Schueller.

High Rise/Fire & Life Safety, *Structural Features - Effect on Fire,* by John T. O'hagan.

High Technology, Dec 86, *Guided Vehicles Set Manufacturing in Motion*, by Jeffrey Zygmont.

High Technology, March 87, *Personal Workstations*, by Jeffrey Bairstow.

Industrial Diamond Review, May 86, *Stone-clad Access Floors for Lloyd's*, by Stan Herbert.

Insight, March 87, *The Campaign for a Higher Office*, by Katie Tyndall.

Intelligent Buildings, *The Services that an Intelligent Building Offers Tenants, Intelligent Building Information Systems, Information Networking Architectures: Integrating the Technologies, The Impact of Information Technology on Buildings and people &*

Intelligent Building Features: A Response to Information Technology Requirements, by Michelle D. Gouin.

Machine Design, Aug 86, *Linking Up with Fiber Optics*, by Douglas Bahniuk.

Manual of Steel Construction, by A.I.S.C..

Means building construction cost data 1987, by William D. Mahoney & Arthur Thornley.

Means Electrical Estimating, Standards and Procedures, by William D. Mahoney, Paul H. DeLong & Robert Crosscup.

Mechanical and Electrical Equipment for Buildings, *Fire Safety,* by William J. McGuinness, Benjamin Stein & John S. Reynolds.

Mechanical/Electrical Systems for High Rise Buildings, *Air Conditioning Seminar*, by Sherwin P. Asrow & Don De Michael.

Multi-Storey Buildings in Steel, *Principles of Design and Construction*, by H. Sontag.

Noise and Vibration Control in Buildings, *Mechanical Systems: Heating, Ventilating, Air Conditioning; Walls, Floors, Ceilings, and Doors* - by Robert S. Jones.

Progressive Architecture, Feb 86, *Electrifying Floors*, by Thomas Fisher.

Progressive Architecture, March 86, *The Hongkong Bank*, by Thomas Fisher.

Recommended Practice for Erection of Precast Concrete, by Precast Concrete Institute.

Seismic Design of Buildings, *Braced Frames*, by James Ambrose.

Standard Specifications Load Tables & Weight Tables for Steel Joists & Joist girders, by Steel Joist Institute.

Steel Buildings Analysis and Design, *Beams - Design Procedures*, by Stanley W. Crawley & Robert M. Dillon.

Steel Design for Engineers and Architects, *Composite Design,* by Rene Amon, Bruce Knobloch & Atanu Mazumder.

Steel Joists & Joist Girders, *Steel Joists, Joist Girders & Fire Resistance Ratings*, by Vulcraft Division of Nucor Corporation.

Steel Joist Institute Technical Digest, Vol. 2,4,5&8, *Spacing of Bridging for Open Web*

Steel Joists, Design of Fire-Resistive Assemblies with Steel Joists, Vibration of Steel Joist-Concrete Slab Floors, Welding of Open Web Steel Joists, by Steel Joist Institute.

Steel Structures Design and Behavior, Second Edition, *Structural Fasteners, Plate Girders, Connections & Composite Steel-Concrete Construction*, by Charles G. Salmon.

Structural Design of Tall Steel Buildings, *Elastic Analysis and Design; Stiffness; Mixed Construction,* by Charles N. Gaylord.

Structural Steel Design, *Composite Design & Multistory Buildings*, by Jack C. McCormac.

Tall Building Systems and Concepts, *Structural Systems; Mechanical and Service Systems,* by Walter P. Moore, Jr., Howard D. Eberhart & Henry J. Cowan.

The Building Systems integration Handbook, *Access Floor and Curtain Wall*, by Richard D. Rush.