DESIGN/BUILD SPEEDS CONSTRUCTION OF NEW COLD STORAGE FACILITY

Using the Design/Build concept satisfied the client's need for fast and economical construction of an addition to an existing distribution center

Shown at top is the main frame during erection. Pictured above is a view of the suspended conveyors, sorting equipment and platforms in the completed structure.

By D. Matthew Stuart, P.E.

IN THE FALL OF 1994, A LARGE MIDWESTERN GROCERY AND RETAIL MERCHANDISE CHAIN CONTRACTED WITH The Stellar Group to provide the design and construction management of a cold storage and distribution warehouse addition to an existing facility. Although this client had never had any experience with a Design/Build firm, they were interested in capitalizing on the ability of such a company to provide for the design and construction of a quality facility within the specified budget and short time frame.

Benefits of the Design/Build method of construction include: single source responsibility during both design and construction; the ability to begin construction during the design process (fast-track); and the capability to provide rapid response to both change orders and construction opportunities due to the inherent cooperation of the construction and design staffs.

The Stellar Group, as a true single source Design/Build firm, was able to provide the desired services through the special collaboration that exists between the design professionals and construction managers of the firm. The Stellar Group is also unique in that it is the largest refrigeration contractor in the world and is therefore capable of providing specialized design and construction services to the cold storage and food processing industry. In addition, the company has available it's own construction crews which can provide installation of certain building components such as insulation (metal panel and roof), proprietary roofing systems, tilt-up concrete wall panels and, of course, complete refrigeration systems.

The owner's program called for a cold storage warehouse and distribution facility of approximately 225,000 sq. ft., along with allowances for a 65,000-sq.-ft. addition. Room temperature requirements were +29 degees F and +34 degrees F for the two coolers while the operating temperature for the freezer was -10 degrees F. This was to be a fully automated facility with product-to-pick conveyor belt modules (4 high) located in the warehouse portion of the building feeding and receiving pallets to and from accumulation and sorting equipment located in the dock.

Minimum vertical clear height requirements in the freezer were 42-ft. while 34-ft. was required in the coolers and dock areas. Other owner requirements included the need for a free-standing Factory Mutual approved MFL (maximum foreseeable loss) wall between the main warehouse and the future addition and the use of Type K expansive cement for the concrete slab-on-grade. The total project cost for this facility was approximately $20 million. The project required 1,256 tons at a cost of $2,114,000. Fabricator and erector on the project was AISC-member Allstate Steel Co.

Pictured at left is the penthouse truss framing.

TRUSSED MECHANICAL PENTHOUSES

Conventional framing for penthouses that house refrigeration air handling units typically use wide flange sections for the support of the equipment, floor grating and adjacent main roof framing. The elevated roof of a penthouse is usually framed with bar joists supported by wide flange spandrel beams.

The footprint of a typical penthouse is configured to take advantage of the main building column grid for support of the perimeter portion of the structure. Because of the heavy equipment loads located within a penthouse it is also customary to add interior column supports, that modulize with the pallet racking system, in order to minimize the span of the interior framing members.

For this project the conveying system, which was located within the flue space of back- to-back tiers of racks, prevented the introduction of interior column supports. This resulted in maximum span lengths of 64-ft. north-to-south and 52-ft. east-to-west at the larger freezer penthouses.

To minimize the steel tonnage required to support the loads over such spans, it was decided to incorporate the wide flange roof and floor members around the perimeter of the structure into parallel top and bottom chords of a Pratt truss through the introduction of vertical and diagonal web members.

Converting the exterior walls of the penthouses into trusses served two purposes. First, as already indicated, as an efficient solution for the support of the gravity loads over the spans encountered and secondly, as a means to provide bracing for resistance to the lateral wind loads. To minimize the spans of the interior framing members for both the floor and roof of the larger penthouses, trusses were also introduced into the internal portion of these spaces. To provide for clear access between the verticals of these members, a Vierendeel configuration was required in the interior panels of the trusses. The equipment layouts did, however, allow for the introduction of diagonal web members at the exterior panels of these same trusses. Combined penthouse roof and floor, dead and live loads, for this project did not exceed 200 PSF.

Shown above is the wood isolation base at the column base.

Sub-Purlin Roof Framing

In the loading dock area of this facility, support of suspended access platforms and sorting equipment for the conveying system was provided from the roof framing. This was required in order to maintain a column free space within the dock. Due to the 72-ft. clear span of the dock and uniform platform and equipment loads of 500 PSF, 52-in.-deep DLH longspan joists were specified. The hanger supports for the platforms and equipment were to be installed by the conveyor vendor on a 10-ft.-by-10-ft. grid. It was initially anticipated that costly field strengthening of the webs of roof joists at the hanger attachments would be necessary unless a framing scheme was developed to eliminate the need to attach directly to the joists. This problem was solved by using 10-in. deep wide flange sub-purlins spaced at a 5-ft. on center that spanned 10-ft. between the DLH joists.

The conveyor vendor was instructed to attach hangers only to the wide flange members during installation of the system. The joist supplier was instructed to either manufacture the webs of the DLH members on the same 5-ft. grid as the sub-purlins or design the top chord of the joists with sufficient capacity to support the sub-purlin reactions between panel points. Because of the large end reactions that resulted from the span and loading conditions associated with the 52-in. DLH joists and other similar adjacent roof framing members, it was determined that wide flange beams were better suited for the support of the roof joists in this area of the building rather than fabricated joist girder members.

Lateral Resisting Systems

Typically, lateral resistance in storage and distribution warehouse facilities framed with structural steel is provided by vertical X or K-bracing located along the perimeter walls. In the case of cold storage facilities, it is important to locate the bracing as close as possible to the center line of the building axis in order to mitigate the effects of thermal movement of the steel frame during temperature “pull-down” of the freezer enclosures. For the freezer and loading dock portions of this facility, vertical X-bracing was used for the lateral stability of the structure.

In the non-frozen foods, or cooler, storage area of the building the lack of interior walls between the loading dock and pallet rack area and the continuous nature of the dock doors on the east and west ends of the building precluded the use of vertical bracing for north-south rigidity. In this portion of the building it was necessary to provide lateral resistance through the use of moment frames via rigid column and joist girder bents. The design of the columns was controlled primarily by the maximum lateral building sway that could be tolerated without impacting the design of an adjacent firewall. Joist girders were designed for combined roof dead and live loads and reversible wind moments resulting from the frame action.

All lateral loads imposed on the building were distributed to the X-bracing or rigid frames by the metal roof deck diaphragm. Both the gauge of the deck and the weld attachment pattern were particularly critical in the loading dock areas of the building. This was because of the relatively large span-to-depth ratio of the diaphragm between the end wall X-bracing located on each side of these column free areas. Typically, wide flange sections were used at the roof in lieu of bar joists at the spandrel conditions associated with the X-braced bays because of the magnitude of the horizontal diaphragm collector forces that accumulate at the bracing locations.

Joist and Joist Girder Load Tables

The recommendations of the standard code of practice for the Steel Joist Institute require that loading diagrams be provided for joists and joist girders that are subjected to loadings other than that listed in the allowable load tables for each type of section. This would include loadings other than uniform for joists and regularly spaced uniform concentrated loads for joist girders.

Providing specialized loading information to the joist supplier allows the manufacturer of the members to both design the sections properly and provide the most economical section for the imposed loads. Unusual and specialized non-uniform and concentrated loads imposed on the joists and joist girders for this project included; suspended refrigeration air handling units and condensers located in the loading docks, roof top ammonia piping and control groups, suspended conveyors, suspended empty pallet storage racks, roof top gypsum board and concrete paver fire protection system, reversible wind end moments, snow drifting and axial loads resulting from diaphragm collector forces.

Because the number of different joists and joist girders effected by the special loads were so numerous it was decided that rather than provide a load diagram for each condition it would be more efficient to tabulate the loads based on a standard load diagram. For this particular project, the joist manufacturer designed and supplied specially sized joists and joist girders to satisfy the requirements of each individual load diagram.

This method of designing and manufacturing specially loaded members allowed for considerable material savings over that which would have been required had standard joists and joist girders been supplied for a general load capacity envelope. Our experience since this project has indicated, however, that quite often many joist manufacturers are unable to provide savings using this method. This is because engineering and manufacturing costs can sometimes more than offset any savings in materials. Because of this, standard joist load tables developed for subsequent Stellar Group projects have included an alternate KCS series joist that provides a load resistance envelope capable of supporting each special load listed.

Special Construction Details Interior operating temperatures for the cooler and freezer portions of this project ranged from 34 degrees F to -10 degrees F, respectively. Operating temperature for the loading docks was also 34 F. Maximum temperature and humidity differentials anticipated between the interior operating conditions and the exterior ambient conditions dictated the need for special insulating and vapor barrier requirements.

Some of these requirements that effected the detailing and construction of the steel structure are as follows. To provide continuity of both the underfloor insulation and vapor barrier, oak blocks were used to support the base of the steel columns between the bottom of the base plate and the top of the concrete footing or pier. The thickness of the wood block was equal to the rigid insulation that is located between the wear slab and the sub-slab. Rigid insulation blocks with compressive strengths in excess of 1000 psi are also sometimes used in lieu of oak. In order to insure continuity of the foam filled metal skinned sandwich wall panels that serve as both the insulation and vapor barrier around each individual refrigerated room or space, it was necessary to provide separate and independent structures on each side of the insulating wall.

This condition results in the need for double lines of both columns and parallel framing members on each side of the wall. The structures on each side of the wall must be free standing and capable of providing their own lateral resistance. The number of different spaces, temperatures and future room conversions required by a particular project can therefore have a large impact on the structural complexity of a given building. For this project seven adjacent but separate steel structures were constructed in order to provide two freezer, two cooler and three separate loading dock areas.

Modification of an Existing Exterior Wall

At the south end wall of the existing loading dock, it was necessary to modify the structural steel to allow for a column free passage way between the existing building and the new connector structure. The modifications included the removal of two load-bearing columns that supported the existing roof and one line of lower girts that provided support to the exterior metal wall panels.

The solution used to remove these members without compromising the support of the existing roof involved the conversion of the structural steel portions of the wall that were to remain into a truss. The resulting structure allowed for three previous spans of 24-ft. to become one clear span of 72-ft..

This was accomplished by first installing new diagonal and vertical members between the existing roof spandrel beam and the highest wall girt which was to remain. The upper portions of the two columns which were to be removed were not demolished to allow for these remaining elements to function as truss verticals as well. By installing the new members indicated and strengthening the connections between the existing remaining structural members, a Pratt truss was constructed using the roof spandrels and the wall girts as top and bottom chords respectively. All remedial work was first completed prior to the scheduled demolition thereby eliminating the need for any temporary shoring.

Two connecting structures were required between the existing building and the new facility. At one location, the loading dock connector, the building was constructed as a refrigerated space to provide enclosed access between the new and existing buildings.

A second structure was required to support the main refrigeration piping across that area of the project intended for the future cooler expansion. Initially it was thought a temporary pipe bridge would be constructed to serve this purpose.

However, analysis of long term economic considerations and the desire to avoid any conflicts with the construction of the future cooler resulted in another solution. It was decided to design and build a portion of the future roof to serve as a means of permanently supporting the piping. The area of the roof constructed included one transverse bay of the future cooler. The design of this structure included provisions for the anticipated future loads, including an adjacent penthouse, and the requirements of an independent freestanding exterior structure.

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