Case Study: Framing an Engineered Floor

by Andrew DiGiammo

Parallel-strand lumber, floor trusses, and steel I-beams solved the problem of long spans and cantilevered loads in this second-story addition

As a design-builder specializing in custom waterfront homes and challenging renovations, I encounter a lot of unusual structural problems. When my design involves long spans or heavy loads that exceed the capacity of ordinary sawn lumber, I turn to manufactured products like steel beams, engineered timbers, wood I-joists, and floor trusses.

Steel, trusses, and engineered wood products expand my range of design options. But because I also build all my own designs, getting the job done on schedule and making a profit are important concerns. Although steel is light, strong, and economical, as a builder I often prefer to use engineered lumber because it speeds up and simplifies the framing. Whenever we're working with wood products, my carpenters can use the saws, hammers, and drills they are familiar with.

In new construction, engineered lumber is generally a luxury, not a necessity. It's usually more economical to design the building with bearing walls and girders that enable you to frame with sawn lumber. In remodels, on the other hand, you often have to work with existing bearing structures. In those cases, sawn lumber won't always meet the design requirements. In choosing materials for those tougher jobs, I have to balance design considerations with practical job-site concerns.

A good example is a second-story addition I designed and built last year in Swansea, Mass. There, I wound up designing and building a hybrid floor system that used PSL (parallel-strand lumber) girders, a big steel girder, and custom floor trusses.

The Problem

My customers wanted a large master bedroom and bath with a whirlpool tub and shower, and an adjacent nursery. To make room for all this plus a stairway required a lot of floor space. The existing house was only 24 feet wide, so I decided to cantilever the second floor 3 feet beyond the existing side walls of the house on both sides.

At one end of the existing house, a previous addition had been built at a 45-degree angle to the original building. Between the original house and the first addition, a small connecting link with its own shallow-pitched roof was in the way. Because the roof of this angled "link" shed water from the rest of the building's roofs, it had to remain undisturbed. So while cantilevering over the sides of the building, I also had to make a 6-foot cantilever over one corner of the end as well.

To complicate matters further, the owners liked the downstairs floor plan the way it was — but there were no interior bearing walls that could support the new floor loads above. Whatever floor system I built had to span the full 24 feet, bearing only on the existing exterior walls.

The final concern was time. We intended to rip the roof off a perfectly sound, well-kept house with people living in it, and we needed to get the new structure buttoned up fast. My plan was to start tearing off the roof early in the morning, and by the end of one marathon day have a new second-floor deck framed and sheathed so we could tarp over it.

The Solution

Design considerations and job-site production concerns both factored into my choice of materials. I needed exceptional strength, combined with ease of assembly. Knowing I had to span 24 feet, sawn lumber was out of the question.

Truss cantilevers. For creating the cantilevers, I chose open-web floor trusses — they were the most economical product that had the required strength (see illustration). For one-third of the original building's length, they would span the 24-foot width between the original bearing walls, and project 3 feet beyond on both sides. For the rest of the building's length, a second set of trusses would run parallel to the building's long dimension, and in one corner they would project out 6 feet over the roof of the connecting link to the first addition. The trusses would provide me with ready-made

chases for my new ductwork, plumbing, and wiring. And just as important, they could be quickly set and nailed into place by my five-man crew.

PSL girders. To support the trusses that ran the long way, I used four girders, spanning the 24-foot dimension of the house. This provided four bearing points for each truss. Using four girders instead of two decreased the load on each girder, making them lighter and easier to handle. It also enabled me to place girders at critical points like stairwells and cantilevers, where beams or headers would be needed anyway.

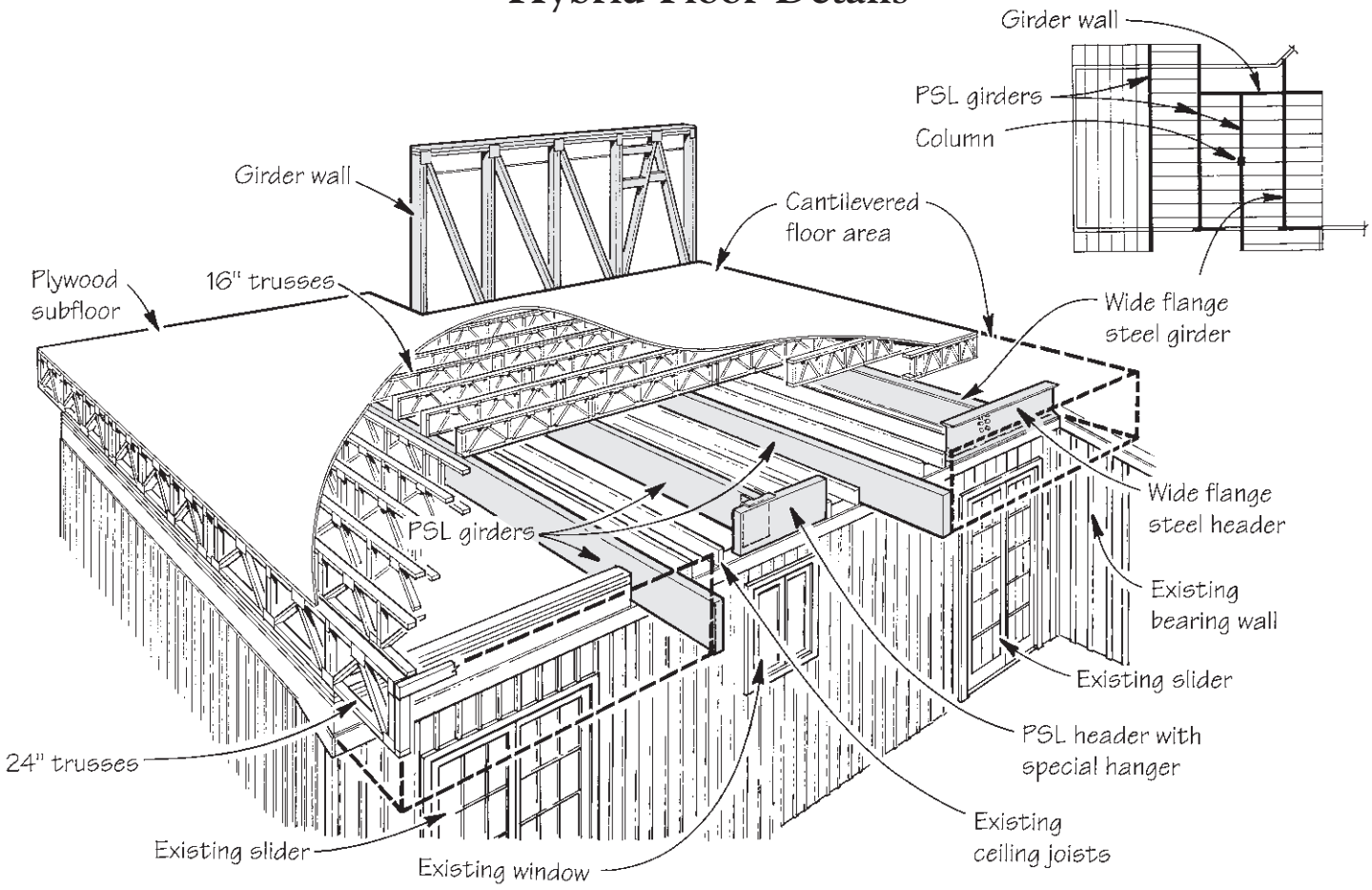
There was another important structural reason for using four girders: Because of the smaller load on each girder, there would be smaller loads at the supports. The existing exterior walls and foundation had to carry all the weight of the new second story. Without doing extensive, destructive testing of the soil and the concrete used in the original foundation wall, I felt safer introducing smaller loads in more areas, rather than large loads in fewer. Also, the two extra girders helped to make a more substantial tie between the existing exterior bearing walls.

The choice for materials for the girders came down to steel or engineered lumber. In the end, I used a combination of both. For three of the girders, I chose PSL timbers, sold under the brand name Parallam (Trus Joist MacMillan, 200 E. Mallard, Boise, ID 83706; 800/338-0515). PSL is readily available in the dimensions and lengths I needed, and unlike steel, it can be cut and drilled with carpentry tools. The project schedule was also important: I didn't want to waste precious time bolting together LVL members or attaching nailing plates to steel. PSL is, however, much heavier than steel. But I would be paying hourly for a crane rental anyway, so I could easily lift the solid PSL timbers into place.

Steel girder. The load calculations showed that PSL timbers would work for all the beams *except* for the support of the 6-foot cantilever area. There, I designed a 9-foot 6-inch girder wall (see photo) to carry a large roof load to the floor. To carry that hefty load, I decided to use a wide-flange steel girder, because it would be substantially lighter and less expensive than two comparable timbers.

For carrying beams, steel is sometimes better than engineered wood. Steel is more complicated to work with, because of the special cutting and fastening tools it requires, and because you often need to attach wooden nailing plates to it. But for spans longer than 20 feet with large loads, steel can still be the most

Hybrid Floor Details



The loads from this second-story addition are carried mainly by the existing exterior walls below. The author added only one interior column, which was hidden in a first floor closet (see framing plan, upper right). On the left end of the house, open-web floor trusses span the entire 24-foot width and project 3 feet beyond the existing first story at each end. The other floor trusses run parallel to the length of the house and cantilever 6 feet. These trusses are supported by three PSL girders and one steel girder. A girder wall helps carry the roof load to the steel beam, and also supports the end of one of the PSL girders.

economical choice. On those spans, engineered lumber is cheaper than steel only if you can install it without a crane, or if the beam is going to be exposed and needs to have an attractive finish.

On this job, I needed a crane to put up the trusses anyway, and my crew has enough experience with steel that I knew we could install the beam in a reasonable amount of time. And the beam would be buried in the structure, so there would be no added expense to dress it up for the sake of appearance.

If your crew isn't comfortable with steel, you can get comparable strength with engineered wood beams, though the wood products will be heavier and cost more. If the beam is exposed, however, you might save money with wood. Either a glulam or a PSL timber can have a nice finished appearance — the choice depends on your client's preference.

Posts and connections. Engineered members can span longer distances and carry heavier loads than sawn stock. But this means that there will be heavier point loads and reaction forces, particularly where beams meet posts and posts bear on foundations. So you have to be sure to use the proper hangers and fasteners.

Using four girders instead of two reduced the loads at the ends of each girder. But I still had to pay close attention to how these point loads were channeled down to the foundation. I had particular concern in two areas. In one place, a PSL girder was going to bear directly over an existing window. There, we fastened a PSL header to the existing plate above the window, then hung the girder from the header using a special metal hanger. At another point, the steel girder was going to bear over an existing patio door. For that spot, I had a wide-flange steel header fabricated, and we hung the girder off the header with a bolted connection made of steel angles.

Two PSL girders cantilevered out over the exterior bearing walls. We bolted those to the existing plate with steel brackets. A triple 2x4 post under each of these beams carried the load down to the foundation.

The third PSL girder terminated at the stairwell. We hung that end from the girder wall with a specialty hanger and installed another post in an existing closet wall to carry part of the load directly down to the existing center beam.

After setting and fastening all the girders, we hoisted the open-web trusses into place and fastened them to the beams. The PSL girders provided ideal bearing surfaces for the trusses. They were perfectly straight, and nailing was simple and fast. This enabled my crew of five to build the entire floor deck in one long day, according to schedule.

The combination of PSL girders and open-web trusses enabled me to create a dynamic floor plan that met all of the owners' special needs, without altering the existing floor plan below. The hybrid approach also made fast, relatively easy work of a complex floor framing system. The end product was a stiff, level floor deck with plenty of space in which to run mechanical systems.

Looking back, I'm pleased with all the special products I used in this project. The PSLs were ideal for their role: strong, straight, and easy to use. The trusses provided good strength for an economical price, and they were quick to install. And the steel girder gave me maximum strength where I needed it.

Engineered wood products, steel, and web trusses open up new possibilities for residential building. There are a lot of products out there, and it takes some time to learn how to use them to the best advantage. It also takes planning and forethought to work them into your production schedule. But if you want to build things that go beyond the ordinary, the investment is worth it. ■

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Built like an oversized truss sheathed with plywood, this girder wall carries roof loads from a 6-foot overhang down to the steel girder below.

Scheduling for Engineered Timbers

When you're planning a job with engineered wood, bear in mind that engineered lumber and the special hangers you need are not stocked by lumberyards. That means you need to organize your material lists carefully and order early. You'll probably need heavy connectors for beam-to-beam or beam-to-post connections. Some hangers take three or four weeks to arrive, which can destroy a schedule.

I know from experience which products take time to get. I don't use a beam or connector in my design unless I know that I can have it delivered on time. But if you're the builder for an architect-designed project, things may be different. When an architect who isn't a builder specifies something, he often has no feel for the product. He might look in a catalog and pull out a product that is not stocked by anybody — and when you order it, there could be a ten-week wait.

So before you commit to a project, make sure all the materials that are specified are going to be there when you need them. After you've opened up the building, it's too late to discover that your job is going to be put on hold. The builder, not the architect, is the guy the customer will call up at 2 a.m. when rain is pouring into the bedroom. — *A.D.*