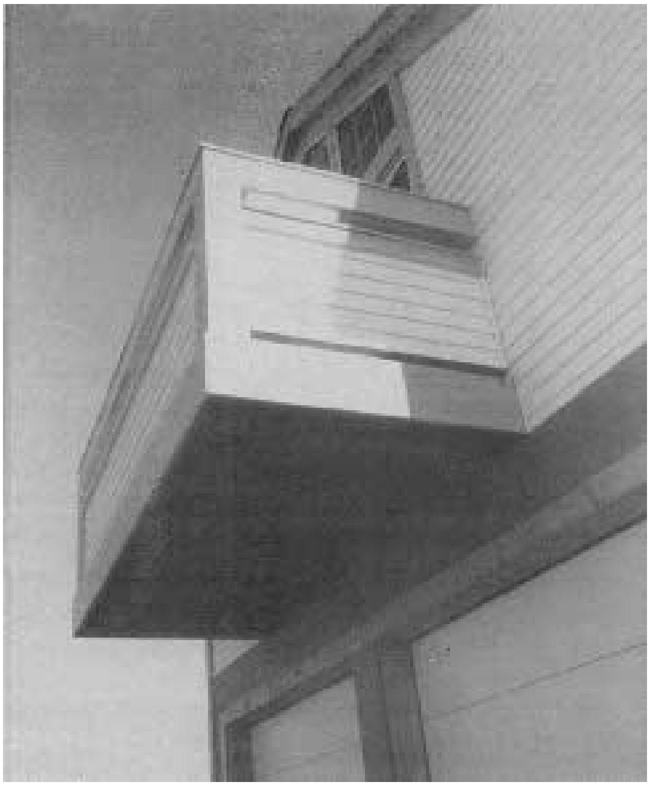
Out On A Limb With Cantilevers



How To Get The Dramatic Effect Without The Bouncy Floor

By Harris Hyman

It's taken years to finally admit it to myself, and then actually to others, but I belong to the Macho School of Structural Engineering. The basic principle of this school is, "Columns are for sissies." This approach, as long as I don't say it outright, pleases my architect clients who want the spaces the way they want them. It also frightens and irritates the builders, who sometimes worry about strength.

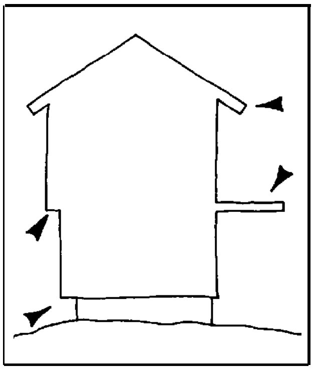
Cantilevers—beams and decks that hang out into space with no visible means of support—seem to fall into the Macho School. Their principal advantage is aesthetic. They are used in a variety of common situations, principally for decks, floor systems and roof overhangs (Sketch 1). As long as they are quite short, they seem to work well. They are also subject to some unusual structural problems.

Bouncy Decks

Any beam can have three types of failure: deflection, bending, and shear. Of these, the most common is deflection, where the beam system is just too soft to do a proper job and either feels weak and bouncy or moves enough to interfere with something else. Shear failure occurs when the beam crushes or tears itself apart, usually down the centerline. Bending failure occurs when the beam breaks, and this is relatively rare, even with supported beams. Perversely, we usually design for strength in bending.

Cantilever beams are particularly bad with shear and deflection. Let's look at an 8-foot overhanging deck made of 2x8s, 16 inches on-center. If the deck is loaded with 50 pounds per square foot, it will have a deflection of one inch at the outer edge.

If the outer edge is supported with a post, then the sag in the deck is only 1/10 inch, about 10 percent of the sag with the cantilever. Try 2x12 joists instead of 2x8s: These reduce the outer-edge deflection to ¼ inch. This is still not as good as supporting the outer edge, but it is probably good enough for a deck.



Sketch 1. In residential construction, cantilevers are used mostly for decks, floor systems, and roof overhangs.

The width of the deck (length of the span) is quite important. The outer-edge deflection of cantilever decks increases with the *fourth power* of the overhang. This means that a deck that is twice as wide has 16 times the deflection. If the width of our deck were reduced from 8 feet to 6 feet, the outer-edge deflection would drop from 1 inch to 3/8 inch.

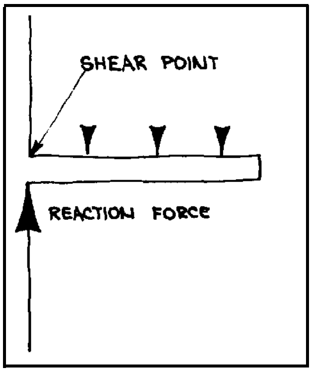
My personal criterion on deflections is that about 1/4 inch to 3/8 inch is perceptible, and that 1/2 inch is noticeable, but okay for exterior decks. This leads to the following table, which assumes joists 16 inches on-center, people walking around, and no outrageous loads like stoves, water beds, or hot tubs:

Maximum Cantilever Deck Span

Joist Size	Indoors	Outdoors
2x6	60"	66"
2x8	72"	81"
2x10	88"	96"
2x12	102"	114"

Deflection isn't the only problem we face, however, with cantilever decks. There is also shear. All of the load is concentrated at the root of the beam. This portion of the beam feels the force that the load exerts downward on the beam right next to the equal and opposite reaction force the building exerts up on the beam (Sketch 2).

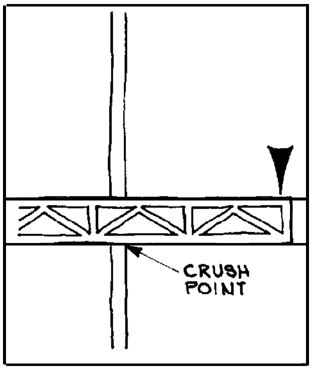
If the table above is used with ordinary construction-grade spruce, shear should not be a problem. But over the past few years, we've begun to rely more and more upon built-up systems, like Trus-Joists and rectangular floor trusses. Are these strong enough? In ordering rectangular floor trusses, the contractor should always submit plans to the truss fabricator and check the shop drawings they provide prior to building the trusses. Most of the truss shops have a computer and plotter on the premises. And if there is a time crunch, it is often possible to go directly to the fabricator and wait while the plotter draws out the plans. The point of checking the plans is to verify that there is plenty of vertical support at the root of the cantilever,



Sketch 2. All of the load on a cantilevered beam is concentrated at the root of the beam, which is loaded in shear. Excessive deflection at the outer end to the beam can also be a problem.

so that an "off-the rack" truss won't be crushed as in Sketch 3.

I was unable to fmd the shear capacity of Trus-Joists, and from some cursory calculations I suspect that they should



Sketch 3. Floor trusses often need extra vertical support at the root of a cantilever. This should be engineered by the truss fabricator.

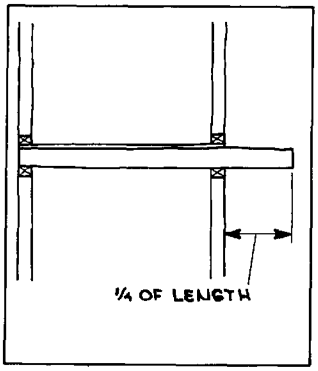
be reinforced with shear plates at the root of the cantilever. It would be wise to verify the shear capacity with the manufacturer, which is best done by sending in plans. This minimizes the opportunity for miscommunication.

Hold Them Down

The next problem with cantilever beams is holding them straight. The roots of these beams must be embedded in the structure, and this is usually done by extending them across the building as floors as in Sketch 4. An old builders' rule of thumb states that the cantilever extension should not exceed 1/4 of the total length. This rule is somewhat conservative, so for most situations it will do the job. The conservative nature of the rule suggests that some careful engineering can push back this edge. The integration of the inside of the cantilever into the building structure can conceivably allow a much longer extension than the 25 percent allowed by the rule.

Insulation and Vapor Barriers

The last problem with cantilever decks is thermal protection. The beam structure extends from the inside of the building to the outside, making it difficult to get a continuous insulation layer, vapor barrier, or even an infiltration barrier. So, here is a request to you



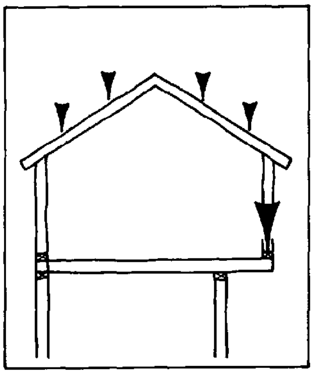
Sketch 4. For solid anchorage, a conservative rule of thumb states that the cantilevered section of a beam should not exceed 1/4 of its total length.

builders and designers out there for some help in detailing an elegant insulation scheme for the root of a cantilever deck.

Garrisons, Bumps, and Beams

There are a couple of other cantilever situations that demand attention: building overhangs and beams. The style often called the "Garrison" is a typical example of overhang. It is also common to use cantilevers under bulges like bow windows, and even to extend the bow windows up to the second floor and the roof.

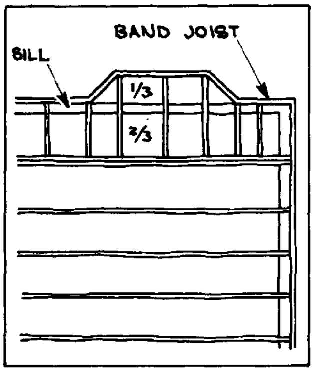
Deflection is rarely a factor for overhangs, but shear can be quite serious. In the Garrison (Sketch 5), the cantilever



Sketch 5. In Garrison-type houses, the cantilever bears excessive shear loads, since it supports roof and wall loads. Use at least 2x10s, or use fabricated joists with caution.

bears not only the interior load of the building, but also the weight of the wall and half the load on the roof. Two-by-tens are the minimum sized joists that should be used on a Garrison or similar structure, with total building widths up to 24 feet. The joists on this type of building should be long and carefully tied into the rest of the structure. Here, even more than with decks, extreme are should be used in working with fabricated joists, since our experience with excessive shear loads has been gained with full dimensioned lumber—not with the new built-up products.

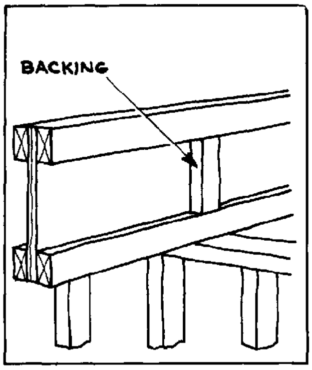
Bulges, unless they extend up to support the roof eaves, should present few problems for cantilevers. They are usually small, and generally they are lightly loaded. If the bulge requires joisting against the direction of the floor system, the bulge width should not be more than 1/3 of the length of the cross joists (Sketch 6).



Sketch 6. Bow windows and other bumps are easily framed with cantilevers. In general, the overhang should not exceed 1/3 the total length of the joists when framed perpendicular to the floor system.

Special beams, steel, and ply-beams are more complex in cantilever situations. Steel beams derive their economy from placing the weight of the steel out by the flange, leaving a relatively weak web. When there are high shear loads on a beam, they must be reinforced with welded (or sometimes bolted) shear plates at the support points. These plates have the effect of thickening the web for a short portion of the beam where the shear load is high. Most steel yards have some fabrication facilities, and can deliver a beam cut to length, with shear plates welded into place. So the use of such beams should be no problem for a contractor.

Ply-beams are similar, with a plywood web and flanges of dimensional lumber. At the support points, the flanges should have backing pieces (Sketch 7) to support them in shear, strengthening the relatively thin plywood webs.



Sketch 7. When used in cantilevers, plywood I-beams must have backing pieces to strengthen the thin plywood web at the shear point. The same holds true for steel I-beams.

Reinforced concrete beams, both straight and cantilever, are real specialty items. They are often prefabricated and require engineering, either privately or by the fabricator. These can be used with marvelous effects, as on George Howe's Clara Fargo House in Maine, which is one of the very best use of cantilevers, ever.

The basic question for the builder to ask with a cantilever is, "Is this really necessary?" If it is necessary—for economy, site, or aesthetic reasons—think it through and work carefully. ■

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