Multifamily

THIRD STREET

On one block in New York City, good design and readily-available materials trump fancy technology.

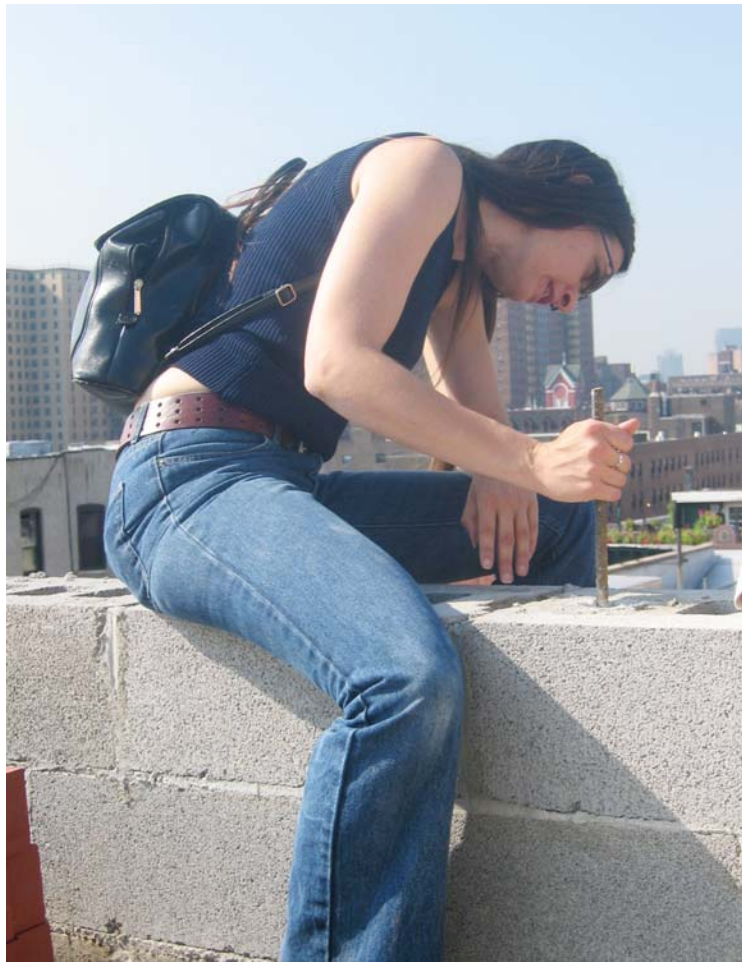
by HENRY GIFFORD

In a departure from the norm of trying to make a building energy efficient by adding fancy gadgets, two apartment houses just built in New York City achieve extreme energy efficiency by combining normal materials with better design. Each building features a minimum efficiency boiler, R-11 wall insulation, standard aluminum-frame windows, and concrete-block walls. The result: the first energy-efficient buildings built for the same cost as code-minimum construction.

One of the new apartment buildings is a six-story, 38-family building at 299 East 3rd Street; the other is a seven-story, 22-family building down the block at 228 East 3rd Street. They were completed earlier this year for $121 per square foot. The buildings were also designed to be healthy for the occupants and exceptionally durable.

The apartment buildings appear so similar to normal construction that the general contractor, Doron Resheff of Resheff, Incorporated, who has 30 years of experience as a builder and is also an engineer, didn't know he was building energy-efficient buildings until GreenHomeNYC's annual tour of green buildings. When he was asked for permission to have the public tour his job site, Resheff said "Sure, have the tour, but what will you show the people except for something different about the front and back walls?" At this point he had finished over one fourth of the job and didn't think he was doing anything particularly unusual.

The developer, Mary Spink, said, "The hardest part of managing new buildings is the complaints about noise between apartments and heating systems that never work." She hired Chris Benedict, a New York City architect known for quality design, to create buildings that would not have these problems. I designed most of the mechanical systems, continuing a long-term close collaboration with her (see "From Ruin to Rehab," *HE* May/June '00, p. 24).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Architect Chris Benedict checks on the work at 299 E 3rd Street, an affordable—to build and to live in—multifamily building in New York City.

Walls

Benedict started by designing innovative walls (see Figure 1, p.26). She worked with building scientists and structural engineers to design the load-bearing front and rear walls with the usual combination of brick, concrete block, insulation, and gypsum board, but rearranged the materials so that the wall could include a drainage plane and an air barrier. The drainage plane manages rain that leaks into the wall, minimizing water damage. The air barrier prevents most of the heating and cooling loads otherwise caused by air leaking through the walls, helps the ventilation system work as designed, and prevents warm, humid air from condensing on a cool surface inside the wall.

Eight-inch concrete blocks support precast concrete floor/ceiling slabs, but that is where the similarity to normal walls ends. A normal wall of this type

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228 E 3rd Street features round metal plates visible on the exterior, which are air louvers for the individual ventilation systems in each apartment.

would have bricks on the outside, touching or almost touching the block wall, and 3 1/2 inches of fiberglass insulation between interior studs. The typical wall has no drainage plane to handle rain that penetrates the brick cladding, and is therefore vulnerable to water problems. Instead, Benedict's wall design has 3 inches of mineral wool insulation installed between the bricks and the concrete blocks. Gypsum board is mounted on studs just thick enough to hold electric boxes. This allows the insulation to be installed in a continuous layer, without the usual interruptions for floor/ceiling slabs, studs, pipes, and wires. This makes it much more effective than a thicker, but interrupted, layer of insulation.

Thoroseal, a cement paste, is brushed on to the outside of the blocks to act as a barrier to air and liquid water. Water that leaks past the bricks can drain through the insulation, which is hydrophobic, and any water that reaches the back side of the cavity can drain down the front side of the block wall. Weep holes and stainless-steel flashing at the bottom of the wall guide the water out of the wall. Any water that makes it further into the wall assembly can dry to either direction, because there is no vapor barrier in the wall.

Another advantage of locating the insulation closer to the outside of the wall is that the thermal mass of the load-bearing blocks and concrete planks is inside the thermal boundary. This reduces the peak heating and cooling loads while reducing thermal movement and cracking of the structure.

These walls fit in the general category of "cavity wall" because of the space behind the brick cladding. Cavities are included for many different reasons, some more sensible than others, and can be built in many different ways. The most common design in the New York City area involves supporting the bricks on steel shelf angles every one or two stories.

Benedict wanted to avoid shelf angles because they can be difficult to attach to precast planks, are notorious for rusting and needing replacement periodically, and are perceived as being very expensive. Instead, the whole height of her brick wall is supported from the foundation at street level.

As in a normal masonry wall, a system of steel wires reinforces the block wall and reaches out with hooks to hold the bricks. The wire in Benedict's wall is longer to accommodate the thickness of the cavity. In most buildings, this wire is plain steel with a galvanized coating that is destroyed by rust, perhaps in a few decades. This is long enough for many people, but since the wire is in the structural walls of the building, it means major structural repairs to the building long before other parts have reached the ends of their lives. Benedict specified stainless steel wire throughout the exterior walls, which will presumably make the building last much longer than it otherwise would have.

One major problem with masonry walls is differential movement of the brick and concrete over the years. The concrete continues shrinking for years, which is known as creep, and bricks expand over time. The differential movement may be as much as 1/4 inch per floor, enough to cause big problems. But in these buildings the windows are mounted in the block walls only, not partly in each wall, as in others, and there are no hard connections between the two walls, so the reinforcing wires can accommodate the differential movement and let the two walls move independently over the years. A gap between the top of the brick cladding and the bottom of the coping stones on

Why Install a Boiler in the Basement?

Three reasons a boiler belongs in the basement:

1. The coal can slide down the chute.
2. When the steam condenses in the radiators, the condensate can be returned to the boiler by gravity.
3. The chimney is tall enough to generate enough draft to provide combustion air if you can't use a fan because your city has not yet been wired for electricity.

If none of these reasons apply, then the logical place to put the boiler room is on the roof, which has the following advantages:

1. Having a boiler on the roof is safer, since the products of combustion are less likely to leak into the building.
2. It's easy to get combustion air into a rooftop boiler room: Put a hole in the wall and install a louver.
3. There are huge fuel savings because of reduced standby losses: The shorter chimney generates much less draft. (Don't try this with a chimney-vented atmospheric gas combustion appliance, which needs a tall, hot chimney to remove combustion products.)

the roof, which rest on the top of the concrete block wall, prevents the movement from dislodging the coping, and will gradually close up over the years.

Since the windows are installed in the block wall only, they are not floating partway between the blocks and the bricks; this makes it easy to connect the windows to the air barrier. Caulk is applied on the interior of the block walls between the windows and the flashing to make the connection. The caulk is located where it is thermally stable, dry, and protected from UV light, and so is expected to continue functioning for the life of the building. No caulk is applied to the exterior of the building. This leaves an untreated joint between the windows and the bricks, which allows some air to leak through the wall cavity, which can dry the wall after a rainstorm.

The walls on the sides of the building are entirely different. They support only their own weight, not the weight of floor/ceiling planks. Since they are lot-line walls, they have no openings for windows or doors. They are also built with 8-inch concrete blocks, but are finished on the outside with 3 inches of foam insulation covered with stucco. This general category of wall system, known as exterior insulation and finish system (EIFS), is notorious for failure. Delaminating of gypsum sheathing results from water entry at window openings. These walls have no gypsum sheathing or windows, which makes them much less vulnerable to failure. This type of wall is simple and inexpensive, yet has a continuous insulation layer. Thoroseal applied to the interior side of the concrete block sidewalls acts as an air barrier.

The air barrier at the exterior walls of the building continues to the walls between apartments, which are built using the airtight drywall approach. The gypsum board is caulked to the floor and ceiling, and the electric boxes are airtightened with duct mastic. This makes each apartment an airtight compartment. Blower door testing on each apartment showed that the median tightness is 1.2 ACH/hr at 50 Pa, considered very tight. The New York City building code requires soundproofing between apartments, which probably cannot be achieved without air tightening. Since this part of the code is routinely ignored, it is difficult to say whether air tightening is an extra or not.

When we have tours of the buildings, we play a boom-box radio very loudly in one apartment and take the visitors to the apartment on the other side of the wall. We love to watch the faces in the crowd because everyone who has ever lived in an apartment grins upon realizing it is difficult or impossible to tell whether the radio is playing.

We Built It Tight, Now We'll Ventilate It Right

Air tightening helps make the ventilation system work. Fans continuously exhaust air out of each bathroom and kitchen. Air is drawn through trickle vents located in the window above the hot water convector heater in each bedroom. If the apartments had air leaks all over, air would be fed to the exhaust louvers from the nearest leak without passing through any other rooms. Because of air tightening, air moves through each bedroom, through the common areas, then out through the bathroom and kitchen vents, providing continuous ventilation to all rooms at all times. The trickle vents and airflow regulators at each air intake are the only materials in the building that are not available from a local supplier.

In a typical apartment building, the ventilation system is a vertical duct connecting a stack of bathrooms or kitchens to a fan on the roof. Automatic fire dampers and thick fireproofing on the ducts are supposed to stop spread of smoke and fire through the system. However, central ventilation systems are

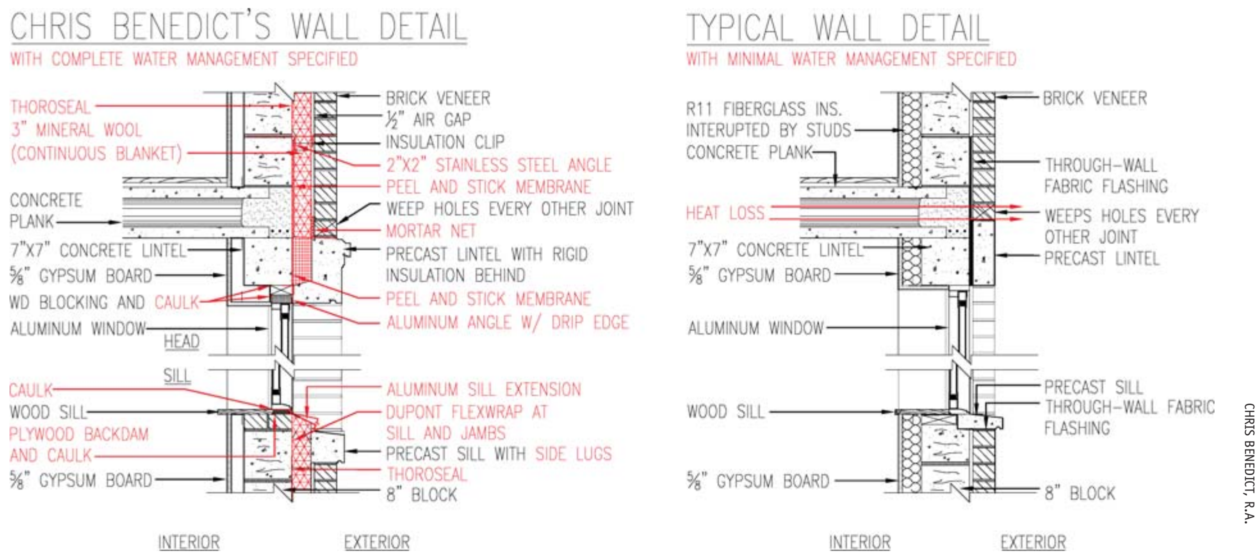

Figure 1. Chris Benedict's design puts the insulation close to the outside of the wall, keeping most of the thermal mass inside the thermal boundary, which cuts peak heating and cooling loads while making the structure more stable. The insulation forms a continuous layer, interrupted only at windows, which avoids the "thermal nosebleed," where plank backs up to the bricks in a typical block-and-plank wall.

notorious for overventilating upper-floor apartments and underventilating lower-floor apartments, and Benedict didn't think it made much sense to build airtight compartments and then connect them with air ducts.

Instead, she designed separate systems that exhaust the air out the sidewall of each apartment, using the existing holes in the concrete planks for part of the ductwork (see photo, p.28). This system violated three parts of the New York City building code, including the provision prohibiting mechanical exhaust out the sidewall of a building. On the sidewall venting issue, she argued that a bathroom or kitchen with a window is not required to have mechanical ventilation, but yet it vents out the sidewall. She got a special waiver for the system she designed, which uses a quiet inline Panasonic fan behind an access door in a closet ceiling, pulling air from the bathroom and kitchen, and pushing it through the hole in the plank and out through a louver on the exterior wall of the building.

This system uses much less electricity per apartment than a typical roof fan system uses, cannot move sound, smoke, or fire from one apartment to another, and is much cheaper than a typical system. It is so much cheaper that even the ventilation subcontractor admitted that it was cheaper. It also avoids the problems associated with roof penetrations that require the coordination of roofers, carpenters, duct installers, and electricians. We have 112 apartments in 29 buildings operating with this ventilation system, many for more than five years, with no complaints.

Avoiding overventilation, and cutting air leaks to a minimum, both help to reduce the peak heating load to a fraction of what it would otherwise be. If the heating system is sized by guessing, these reductions in load have no effect on heating system size, but Benedict does her own heat load calculations, and these, of course, take into account the low infiltration load. Thus, the money spent on air tightening yields savings by allowing smaller heaters, piping, and pumps and a smaller boiler, and the improved ventilation system saves money on both the ventilation system and the heating system.

Now Let's Provide Just Enough Heat

A convector heater that is supplied with hot water pumped from the boiler heats each room; a thermostat controls each heater. The thermostats are the nonelectric knob type, which have wax-filled capsules in the head, and last for decades. These capsules expand and contract in response to changes in room temperature, thereby varying the flow of water through the heater. The thermostats are limited to a high of 73°F, although the tenants can set them lower if they want to.

These thermostats prevent uneven heating or overheating, saving huge amounts of energy. They permit a smaller boiler because without thermostats, during the coldest night of the year the boiler would have to adequately heat the windward side of the building while overheating the leeward side of the building. But with thermostats, the boiler will never see a load higher than what will adequately heat each apartment on the coldest night of the year, so the thermostats pay for themselves on construction costs by allowing the boiler, piping, and heating water pump to be about 25% smaller than they would otherwise have to be.

The result is a 38-family building getting heat and hot water from a boiler—rated at 1,082,000 Btu/hr input and 872,000 Btu/hr output—so small that it has a 10-inch flue. To put this in perspective, a single-family house or a small row house in New York City might have a 10-inch flue.

The boiler heats domestic hot water in coils, and an electronic mixing valve accurately controls the temperature to within a few degrees of 120ºF. A 100W pump continuously circulates domestic hot water through the hot water supply and return piping, all of which is insulated with 1 1/2 inch wall thickness fiberglass insulation. The first 3 feet of each branch off the mains is also insulated, minimizing heat loss from the piping—this is not a problem in winter because the heat lost from the piping stays in the building, but in the summer it increases the air conditioning load.

Locating the boiler room on the roof means using cheaper real estate than basement or ground-floor space, and saves the space and cost of a tall chimney (see "Why Install a Boiler in the Basement?" p.25). A tall chimney pulls lots of air through the hottest part of the building—

A Useful Comparison

535 East 5th Street is a 30-family building completed by the same developer, Mary Spink, in 2001. It is a useful comparison because it is typical block-and-plank construction with fiberglass insulation between interior studs, no attention to air tightening, and a typical ventilation system that overventilates much of the building (see Table). However, it also has a boiler on the roof, a thermostat in every room, and accurately controlled hot water supplied by the same boiler that makes heat. In other words, it has the same heating system and boiler as Benedict's buildings, but is otherwise typical construction.

Table. Comparison of Energy Use

	Average NYC Apartment*	Metered Consumption at 535 E 5th	% of Average	Benedict's Buildings (Projected)	% of Average
Heat	24 Btu/ft^2/HDD	6.58 Btu/ft^2/HDD	27	3.6 Btu/ft^2/HDD	15
Hot Water	103,262 Btu/ft^2/yr	17,051 Btu/ft^2/yr	16.5	15,500 Btu/ft^2/yr	15
Combined	219,543 Btu/ft^2/yr (53% heat)	48,981 Btu/ft^2/yr (65.5% heat)	22	33,400 Btu/ft^2/yr (54% heat)	15
Total $/yr		$603		$410	

* These figures were reported in "Fuel Use in Multifamily Buildings," *HE* Nov/Dec '99, p. 30.

the boiler—all day and all night, including when the boiler is not firing. A short chimney pulls much less air when the boiler is not firing, saving perhaps 30%–40% of the annual fuel bill.

I chose a normal cast-iron boiler with a fan-forced on/off gas burner, which runs at about 82% steady state efficiency. (Never mind that it is not a steady state device!) A high-efficiency condensing boiler might run at 97% on a good day, or 92% at other times, averaging perhaps 94% efficiency. The cost of fuel for heat and hot water for 299 East 3rd Street is expected to be about $410 per apartment per year, for a total of $15,600 for 38 apartments. A more efficient boiler might save about 12% of that, or $1,870 per year, plus whatever standby losses are avoided with sealed combustion equipment. However, there are reasons why I did not choose a more efficient boiler.

A more efficient arrangement would be a single high-efficiency sealed combustion boiler and an indirect water heater (tank with a coil), which I would specify for a small building, but these buildings are too large to be supplied with hot water from a single tank. Multiple tanks are expensive to buy and complicated to pipe properly, as are multiple small boilers; thus, I thought they would add too much cost and complication to justify the savings.

Four years ago, Mary Spink built a building around the corner at 535 East 5th Street, with a similar low-efficiency cast-iron boiler. The cost for repairs during those years has been only $300 for a new ultraviolet sensor on the gas burner. This is another reason I did not choose more complicated heating equipment—because of parts that are hard to replace, a lack of familiarity among service people, and other reasons, for instance that complicated equipment costs more to fix! Fifth Street is a good comparison building because it was built with normal construction methods but a well-designed heating system. It uses only 22% of the energy an average New York City apartment house uses for making heat and hot water (see "A Useful Comparison"). This shows that the biggest area for savings in buildings of this type is in the heating system. This is because it is harder to deliver heat evenly to large buildings, which increases the chances of people's controlling temperatures by opening windows. More panes of glass in a window save no energy if people open the windows, so improving the windows and walls is useless unless the heating system works really well.

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A crane drops concrete planks trucked from the factory. Load bearing concrete block walls hold them up. The metal edge is a "pour stop" where cement is poured around steel rebar to bond the plank to the walls.

Fifth Street is also useful for predicting how much energy Benedict's buildings will use. Since her buildings have better insulation on the hot water piping, the energy used to heat water is expected to drop below 15% of the New York City average. How low the space-heating energy will get is harder to predict, but it will probably be well below 20% of the city average.

Benedict's design for the building envelope could have been improved by specifying better windows and more insulation, but paying for these improvements by saving a portion of the $142-per-apartment-per-year projected heating cost is a hopeless proposition.

Extra Costs for Efficiency and Comfort

Budget for extra costs associated with making these buildings energy efficient, healthy, and comfortable for the occupants, and durable:

$0.00

Electricity Use Is Important Too

The owner's electricity bills will also be very low. I designed a water pressure booster pump system that costs less to install than a normal system, while using less than 5% of the electricity of a normal system, and specified an elevator that is slightly slower than what would normally be used for a building of this height, but which uses much less electricity than a normal elevator would use. Benedict specified stairway lighting that automatically dims until motion sensors detect people coming and turn it up to full power, and energy-efficient lighting throughout the rest of the building.

The outdoor lighting control design I worked out, which should be commonplace, is something I've never seen done elsewhere. Automatic photocells built into fixtures can turn the lights on and off at the right time, but are notoriously expensive to replace. Cheap hardware store photocells mounted separately have a reputation for short lives. Therefore, many apartment house managers prefer time clocks. The problem with time clocks is that pins need to be constantly reset as the times of sunset and sunrise change, which often causes the lights to be on when unnecessary or off when they should be on—unless you know someone who can figure out how to reprogram one of those astronomic models after every time the power goes off.

The solution I worked out, which is cheap and logical, was to have the electrician wire a cheap hardware store photocell to the coil of a $30 switching relay, and wire the relay to switch all the outdoor lighting on and off. This produces the best of both worlds. The cheap photocell is as reliable as a time clock because the photocell sees only the load of the relay coil, but also switches the lights on and off at the right times.

What Next?

This project was completed without any additional money or grants subsidizing the energy efficiency goals for the building (see "Extra Costs for Efficiency and Comfort"). People ask, "Why not get a grant to do what you are doing?" Chris Benedict and I feel that every time someone gets a grant to do something better in a building, it sends subtle messages that without grant money you can't be energy efficient.

Other people ask if we use a checklist to find out whether the buildings are energy efficient or green. No, we have not, nor do we plan to. The most toxic materials are the floor finishes and latex caulking, the apartments are ventilated better than almost any others and have radon mitigation strategies, they are durable enough to stay out of the landfill much longer than other buildings currently being built, and they will use a small fraction of the energy other buildings use. Ironically, they would perhaps not qualify as energy efficient because the walls are insulated to only R-11, because there is no slab or perimeter insulation at the ground floor (because the small energy loss will help dry the masonry walls where they are perhaps most vulnerable), and because the owner doesn't like double-door entrance vestibules. But as soon as we have a utility bill history, we will be glad to compare energy use to that of buildings that pass the checklists.

The other question we get is "Why not put up solar panels?" We have nothing against solar, but feel that it doesn't pay with current low, subsidized energy prices in the United States. Instead of getting grants to bring the price (but not the cost) down to levels at which it pays, we think it would be better for the government to stop subsidizing energy.

Since we can't do anything about that, we are doing what we can: making an honest living proving that over 80% of the energy used by an average apartment house is wasted, and that this waste could be eliminated while making the building more healthy and comfortable to live in, all at no extra construction cost. We encourage people to copy from us and to find ways to beat us by making buildings even more efficient at no extra cost. After that, we can talk about spending extra money on buildings.

Henry Gifford is an uneducated boiler mechanic who designs mechanical systems that actually work. He loves working with Chris Benedict and Mary Spink because they stand up to contractors who say "If we don't do it the way we have always done it, it is not guaranteed".

For more information:

Gas bills for 535 E 5th Street can be seen on Henry Gifford's Web site at www.HenryGifford.com.

Gas bills for 228 and 299 E 3rd Street can be seen on Chris Benedict's Web site at www.ChrisBenedictRA.com.

There will be an open house at 228 E 3rd (between Avenues B and C in Manhattan) on October 1, 2005. The open house is a part of GreenHomeNYC's (www.greenhomenyc.org) and the Northeast Sustainable Energy Association (NESEA's) annual green building tour. Slide shows will start at 10am, Noon, and 2pm.