ENERGY CONSERVATION OPPORTUNITIES IN THE BUILDING ENVELOPE THROUGH THE ENFORCEMENT OF A MANDATORY ENERGY CODE

David R. Miller
Member, ASHRAE

ABSTRACT

The Massachusetts State Building Code has included energy conservation provisions based on ASHRAE Standard 90 for the building envelope and mechanical/electrical systems since January, 1978. As part of its programmatic review the Building Code Commission has been monitoring the implementation of these energy conservation regulations via a plan review service for all non-residential buildings. Since the Commission staff reviews a large portion of new construction building designs, the service provides a vehicle to maintain close contact with both the design and code enforcement communities, but more significant is that it provides a check on the level of energy conservation designed into today's buildings.

The results of this monitoring activity are startling as the staff of the Commission gains insight to the state-of-the-art in energy efficient building design. Three facts are becoming increasingly clear: Standard 90 is inadequate in setting the direction for conservation in new buildings; design professionals need to be sensitized to the energy performance of the building envelope; and construction detailing of building envelope assemblies is frequently deficient. While no quantitative estimate is available of the energy wasted in this latter case, the loss cannot be underestimated.

INTRODUCTION

It would seem that designers of new buildings should take energy conservation considerations more seriously as the price pressures on energy supplies increase. If has been the experience of the Massachusetts State Building Code Commission staff that designers are only going part way toward meeting their responsibilities to incorporate energy efficiency into the building envelope. While they may be paying attention to code values for thermal performance, they tend to treat these values as upset limits to target in their design.

One of the obvious places to improve building design is the building shell. Buildings of the past 25 years often have been designed with large amounts of single pane, highly inefficient glass. Today designers are more aware of the cost penalties associated with using these kinds of design techniques and tend to provide better insulation of the building envelope, to reduce glass areas, to orient the building such that the glazing takes advantage of natural solar heating, and to do whatever is appropriate and cost effective to make buildings energy efficient. Even with this increased energy awareness, there is a need to maintain building codes that will ensure minimum levels of energy efficiency in all building designs and will set the direction for new efficiency standards.

David R. Miller
Energy Program Manager
Massachusetts Building Code Commission
1 Ashburton Place, Boston, MA 02108

ENERGY CODE BACKGROUND

Since January 1, 1978, the Massachusetts State Building Code has included provisions for energy conservation in the design of new buildings. These regulations are based on ASHRAE Standard 90-75, less Section 9, and the Model Code for Energy Conservation. Massachusetts has a uniform statewide building code which must be adopted and enforced by every city and town in the Commonwealth. This serves as an excellent tool to measure the value of building codes in terms of promoting conservation in new building designs. Every building that is designed and built in Massachusetts must conform to the code and, therefore, there are numerous opportunities to check the effectiveness of code standards in setting proper conservation standards.

REGULATING THE ENVELOPE PERFORMANCE

The energy code affects the losses and gains through the building envelope in two primary areas: one is minimizing the losses and gains through conduction and the other is tightening the losses through infiltration. The amount of energy saved through this type of regulation can be significant to the overall energy usage in the building. An indicator of the savings is a study done by the Arthur D. Little Company which suggests that the energy performance increase in a building due to improvements in the envelope resulting from application of the ASHRAE Standard 90 might save 24% of the heating energy usage in a pre-code building versus a post-code building. Our calculations of the energy losses in a single-family residence in the northeast indicate that the building envelope accounts for 76% of the total energy used in a building.

Part of this energy consumption may be attributed to losses through infiltration. One study of houses in the southwest showed that holes in the envelope amounted to a 30% loss in energy. Perhaps even more significant is that the same study shows 59% of the energy used in those single family dwellings may be attributed to cracks beneath the sill plate, around wall outlets, and along duct runs.

BENEFITS OF ENERGY CODE ENFORCEMENT

There are obvious benefits to be derived from enforcing mandatory energy codes. Clearly, there is the direct energy saving accrued by referencing minimum envelope performance standards and having all buildings meet these performance criteria. Further, as construction technology improves and the cost of energy increases, it becomes relatively easy to tighten the code performance values on a uniform basis such that additional energy savings can be picked up over time.

However, there are secondary conservation gains to be accrued from the enforcement of energy codes. Perhaps the one least mentioned but the one with the greatest potential is that of design professional awareness. If architects and engineers become more aware of energy issues in the design profession by having to comply with energy codes, there may be a spin-off into other areas that are not regulated by the code itself. One example of this is in the area of passive solar design. We believe that because designers have had to face minimum performance standards in the building envelope and these standards tend to limit the amount of glass that can be incorporated into buildings, they are now beginning to think more consciously about where the glass is being placed in buildings. Designers are placing the glass such that it maximizes solar gains at the right time of the year while minimizing its usage on those sides which would be detrimental to the energy performance of the building.

ENERGY CODE ACCEPTANCE

Experience with enforcing the energy code over the past twenty months has shown there is good acceptance and enforcement of the building envelope components particularly as they pertain to one and two family dwellings. However, when it comes to non-residential buildings, we have found that the code is not well enforced by the building inspector community.

Among design professionals, we see a split as to code compliance in non-residential buildings. It seems that there is fairly good compliance with the envelope thermal infiltration criteria and much less compliance with the other parts of the energy code. This is not to suggest that designers accept one part of the code at the expense of another part. As will be shown later, there seems to be a number of factors at play with this success/failure of compliance among the energy components.

PLAN REVIEW SERVICE

Beginning with the calendar year 1979, the State Building Code Commission initiated a voluntary plan review service of all new buildings sent out for public bidding. The purpose of this plan review service was three fold: to provide technical assistance to building officials as they attempt to enforce the energy code in the more complicated systems of non-residential buildings; to provide an outreach to design professionals to assist them with understanding the energy code requirements; and to monitor the levels of compliance with the energy code.

REVIEW PROCEDURE

Plans are obtained by the State Building Code Commission on microfilm from the Dodge division of the McGraw Hill Information Systems Company. Staff engineers review these plans for compliance with the appropriate sections of the energy code. The code deficiencies are noted in a letter to both the design professional responsible for stamping the documents and to the building official in the community where the permit will be drawn. Responses from the design professionals are analyzed by staff and reviewed again for compliance with the energy code. Ultimately, the building official is notified whether or not the proposed building meets code requirements.

Since plans are obtained early-on in the bid process, there is the chance for the design professional to incorporate the comments of the staff on the energy code review into the bidding process via addenda. This is a more expeditious method of meeting code than having plans reviewed after the bid process at the time of building permit application when any change to the building would mean issuing a change order or renegotiating the contract.

PLAN REVIEW STATISTICS

During the first six months operating the plan review service, 136 projects were reviewed with notification sent out on every project. Response to date indicates that 55% of those notified have come back to the Commission with either clarification or reevaluation of the design details. Total value of construction review to date is $250,000,000.

ENERGY CODE COMPLIANCE ASSESSMENT

Approximately 90% of the projects reviewed had significant code deficiencies in one or more areas. Code deficiencies are defined as non-compliance in a component that would affect the energy function of the building in a significant manner. It was found that typically designers met the envelope U_o and OTTV values, window infiltration values, HVAC equipment efficiencies, duct construction and insulation, and pipe insulation criteria with minimal effort. On the other hand there were typical areas that were almost always being missed by designers in the application of the energy code to buildings. These included spaces being over-ventilated, HVAC equipment being installed grossly over-sized compared with the loads, inadequate temperature controls, improper application of outdoor design temperatures, and improper domestic hot water heating equipment. It is estimated that failure to meet these minimum code requirements will cost building owners of new 1978 buildings an additional $3,000,000 a year in energy operating costs.

Table 1 is a compilation of thermal values calculated on projects studied in the plan review process. The mean U_o for walls and for roofs in all construction was 25% and 14% respecitvely below code requirements. The overall thermal value for all construction was 30% below code allowance.

It is quite clear from both the reviews of construction documents and the responses received from project designers that many people were not aware of specific code requirements for energy conservation. Yet, in most cases it was found that the building envelope complied with code values, both in terms of its thermal properties and infiltration rates. If this is the case, does ASHRAE 90-75 go far enough in setting envelope conservation standards? Standard 90 says its purpose "is to provide design requirements which will improve utilization of energy in new buildings. . . " If the common design practice today is to meet or exceed ASHRAE, we question if ASHRAE shouldn't be looking toward an improved standard.

ENVELOPE CONSTRUCTION DETAILING

In addition to the specific data checked for energy code compliance during the plan review process, staff became aware of other acute deficiencies in the execution of construction documents. These are referred to as detailing problems, and they show up in almost every project we have encountered. While no quantitative estimates are available of these detailing omissions, their impact on the energy loss through the building envelope may be substantial. One of the most common detailing problems is slab edge insulation for slab-on-grade construction. ASHRAE Standard 90, Section 4.4.2.4 requires that edge insulation extend from the top of the slab through the concrete floor down to some point either under the slab or along the foundation wall. Figure 1B indicates the typical suggested detailing arrangement of this edge insulation. Actual practice as reviewed in our compliance analysis shows that designers are not following the requirement to break slab contact with the foundation wall. Typically when we call this to the attention of the designers, they state the construction detailing necessary to accomplish this thermal break is beyond the state-of-the-art today. The detail of Figure 1A is typical of that used by most architects. While this does a good job of minimizing the loss through the floor along the perimeter, it doesn't stop the thermal syphoning effect of the concrete exposed to the cold outside.

A similar area of energy loss through poor detailing is that of concrete slab balconies. Figure 2 shows typical balcony construction in an apartment building where the concrete slab extends from the interior floor right through the exterior wall and projects to the outside on an overhang to act as the apartment balcony. To further aggrevate the situation, heating engineers frequently install some type of baseboard radiation along the perimeter exterior wall. The radiation loses its heat both through the exterior wall and directly into the floor slab. Since concrete is an excellent conductor of heat and heat tends to migrate to the cold, the heat is drawn to the outside through a syphoning effect along the cold concrete slab.

If one could imagine a high-rise apartment building with a number of balconies projecting through the exterior wall, it could be viewed the same as fins on baseboard radiation elements. All these balconies serve to help dissipate the heat contained within the core of the building. A better way to handle this situation would be to break the concrete to concrete contact between the interior floor slab and the exterior balcony. The construction detailing may be somewhat more involved but there are ways to handle the problem and the energy savings and comfort possibilities clearly offset any construction burden.

Beyond these detailing omissions, our plan reviews have uncovered other types of detailing which tend to be so all-encompassing that they will never be built in the field. An example of that of insulation applied behind spandrel construction, where the units were designed to be hung on clips from the structural framing members. The architect detailed fiberglass batt insulation to be applied between metal stud framing behind the wall panels. In this particular situation it would be impossible for a mechanic in the field to install the fiberglass as shown in the drawings. With the roofing structural steel in place, and the exterior panels applied, there is no room for the mechanic.

WINDOW AND DOOR INFILTRATION

It was found during the plan review that in very few instances were the infiltration rates for windows and/or doors included in the specifications. In the few instances where infiltration rates were included with the specificiations, we did not see a call for these values being certified according to the appropriate ANSI standard or other equivalent industry sponsored test standards.

Some months ago our office decided to inform window and door manufacturers of the energy code requirements for testing and certification of the infiltration rate. Notification was sent out to all readily identifiable manufacturers; to date we have received 66 window infiltration test reports and seven door infiltration reports. All of these reports are from manufacturers whose main product line is geared toward single family dwellings. In no case did we receive test reports from manufacturers supplying windows and doors for commercial installations.

Of the 66 window manufacturers who sent tests, the average infiltration rate was .217 CFM per linear foot of crack. The lowest rate was .01 CFM per lineal foot and the highest was .47 CFM per lineal foot. ASHRAE Standard 90 requires .50 CFM per lineal foot as the criteria for compliance. This average infiltration rate of .217 is far superior to the ASHREA requirement; a rate of .30 CFM per lineal foot would encompass 90% of the windows tested. Wood, aluminum, and PVC windows with all combination of sliding, casement, and double hung units were included in the test reports.

The reports received on the seven doors reslted in an average of .06 CFM per square foot infiltration with low value of .03 CFM per square foot and a high of .10 CFM per square foot.

The ASHRAE Standard 90 requirement of 1.25 CFM per square foot has no relationship to the door tests reviewed. It is apparent from the results of our analysis that ASHRAE Standard 90 does not go far enough in setting reasonable infiltration limits for windows and doors. If every test report we received showed infiltration rates better than the ASHRAE requirements, then what benefit is there to having an industry standard? ASHRAE should be setting the direction within the industry by requiring at some date manufacturers tighten their infiltration rates for windows and doors. Enforcement of this mandatory code provision is apparently a waste of time and money when one considers that practically any window or door will meet the code requirements.

INSULATING MATERIALS STANDARDS

A 1978 study conducted by the Massachusetts Building Code Commission of the insulation industry and the materials used in that industry concluded that there was no uniform regulatory mechanism to require that insulation materials meet appropriate test standards. The study recommended that existing federal and industry reference standards be adopted into the State Building Code to ensure a uniform quality of insulating materials.

The potential problem by not having uniform test standards is that manufacturers could claim different R-values for the same product when tested in non-standard laboratory conditions. The Building Code Commission did adopt these materials test standards into the State Building Code and they are now enforced on a uniform basis for all insulating materials in Massachusetts. Table 2 indicates the insulating materials covered by the code and the reference standards adopted for testing thermal performance value.

We believe that insulating materials reference standards should be incorporated into all uniform building codes and cited in construction specifications. Energy standards are requiring minimum thermal conductivity values and these values are usually achieved with insulation. It is important to ensure that the insulation materials will perform in some uniform manner.

CONSTRUCTION SPECIFICATIONS

In the course of reviewing plans for new construction, staff also reviewed design specifications to determine whether they included reference to the energy code standards. Again, the level of compliance here was uniformly poor. There are a number of areas where construction specifications impact the thermal performance of a building envelope. Situations such as concrete work, masonry, thermal and moisture protection, and door and window specifications are included in this list.

Under concrete work, the construction should be executed in such a manner that there will be a break in the thermal conductivity between concrete on the inside of a building connecting to another concrete element on the exterior of the building. All joints in concrete work should be keyed to prevent through joints and all joints should be sealed to minimize leaks as much as possible. Leaks serve as a dual problem in concrete work. First, they allow water to enter which may freeze, expand, and result in concrete spalling. Secondly, joints allow the infiltration of air into the building with the associated increased energy consumption.

Masonry materials and in particular concrete blocks have a number of areas that should be specified for energy efficiency. First there is the density of the conrete block and the weight of the block. Most specifiers tend to look at the block in terms of its structural properties, but it also has energy benefits in terms of its thermal mass content. Without specifying the physical properties of the block, there is no way to insure either the application of a mass factor to the building or a straight thermal resistance factor in the calculation of the overall thermal conductivity of the envelope.

When the cores of the block are to be filled with some type of insulating material, it is important to specify the quality of workmanship that is to be exercised in the application of the block. Care should be taken to keep cores free and clear, fill the block as they are laid, keep the block dry at night to prevent soaking the insulation. When using a rigid board insulation it is important to specify the method of application, limiting the number of through connections that will penetrate the insulation. In cavity wall installations keep the air space clear to prevent through contact with the outside surface.

The thermal performance of insulation materials is usually specified in the sections on thermal and moisture protection. For batt insulation this includes the R-Values expected from the insulation as well as the thickness of the insulation. Specifications should include how the insulation will be applied in the building, how it will be fastened, whether it will be friction fitted or stapled. Care should be taken so that all cuts, tears, and joints are taped; insulation should be protected from the weather; and it should not be crushed during installation. For foam board insulation, the K-value per inch or C-value at the specified number of inches should be referenced; installation instructions should include tightly butting joints and minimizing the number of penetrations through the insulating material. For spray-on foamed-in-place insulations the K-value per inch should be specified as well as the average thickness and density of the final product.

Also in section on thermal and moisture protection, the specifications should include adequately ventilating insulated spaces. Ventilation to allow the removal of moisture that may enter the cavity should be provided over insulation particularly where vapor barriers are not installed or where vapor barriers might be frequently penetrated. The proper amount of ventilation should be specified and care should be taken to insure that cross ventilation is accomplished.

The specifications for doors and windows should include that they be tested in accordance with ASTM E-283 or an appropriate industry test standard for infiltration rates. Specifications should include the U-Values of the glazing materials, that doors are weather stripped, that there is an adequate closer on the units with an appropriate lock to insure a tight seal when the units are closed. Installation instructions should note that units are to be set such that they will not rack. Where metal frames are used, these should be specified to have a thermal break in the frame or else the frame will perform thermally worse than the window itself.

CONCLUSION

It has been shown that there are definite conservation benefits in the building envelope resulting from the enforcement of mandatory energy conservation regulations. There are direct energy savings through the increased thermal performance of the building shell. There are also indirect benefits to be accrued by increasing designer awareness around energy conservation issues and by improving material standards and product quality.

Energy codes are not a panacea for the energy crisis in the built environment. Many designers are not aware of the minimum energy requirements presented in the State Building Code. There is considerable lack of attention to construction detailing and specifying energy related materials.

Energy codes do provide a vehicle to treat these problems and to strengthen the requirements for future building energy performance.

TABLE 1: Envelope Thermal Values of Buildings Analyzed in Plan Review

Building Type	U_o Walls				U_o Roofs				OTTV Walls		
	Code required	Mean reported	% deviation	Range of Values	Code required	Mean reported	% deviation	Range of Values	Code required	Mean reported	% deviation
One and two family dwelling	.20	.15	-25	--	.05	.03	-40	.027-.04	- .	-	-
High-rise housing	.30	.24	-20	--	.07	.052	-26	.031-.061	34.2	25.5	-25
Low-rise commercial	.25	.19	-24	.11-.248	.07	.063	-10	.048-.073	34.2	24.7	-28
High-rise commercial	.30	.21	-30	.14-.23	.07	.063	-10	--	34.2	26.3	-23
Schools	.25	.20	-20	.12-.23	.07	.05	-29	.042-.079	34.2	20.0	-42
Industrial	.25	.17	-32	.088-.267	.07	.066	-6	.05-.07	34.2	11.2	-66

TABLE 2: Insulation Materials Standards

Material	Federal Specification	ASTM Test
Mineral Fiber		
Blanket/batt	HH-I-521E	C665-70
Loose-fill	HH-I-1030A	C-764-73
Mineral Cellular		
Perlite	HH-I-574A	C549-73
Vermiculite	HH-I-585B	C516-67
Organic Fiber		E84-77
Cellulose	HH-I-515C	C739-77
Organic cellular		
Polystyrene board	HH-I-524B	C578-69
Urethane board	HH-I-530A	C591-69
Flexible unicellular	HH-I-573B	C534-70

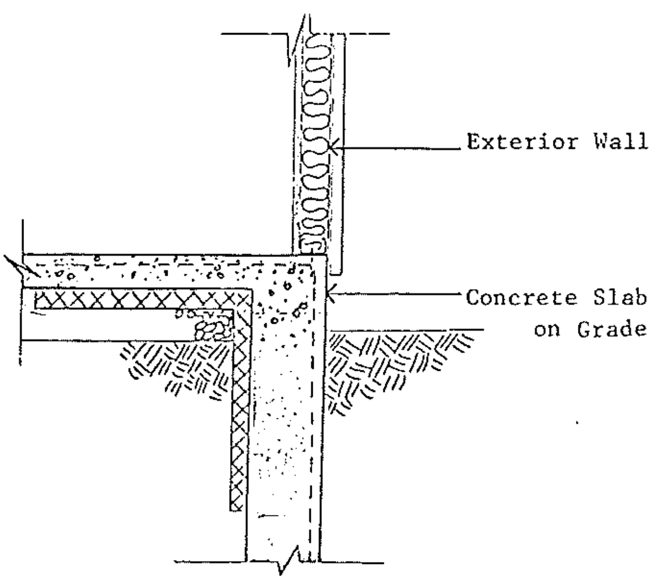

Figure 1A

TYPICAL PRACTICE - SLAB EDGE INSULATING

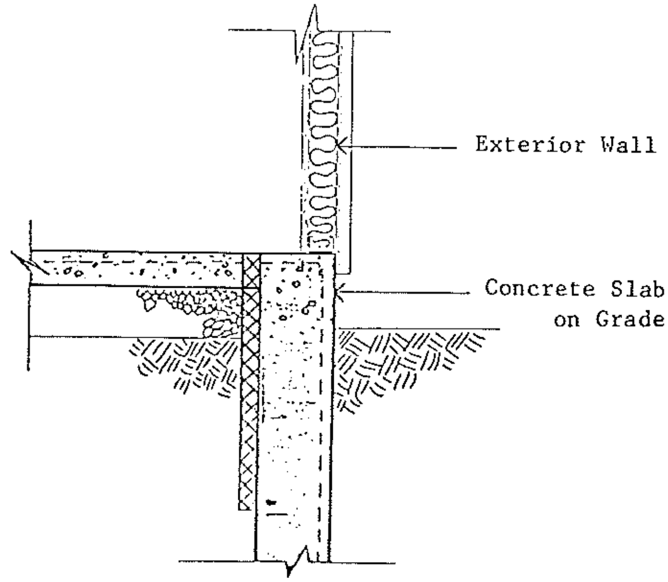

Figure 1B

CODE REQUIRED SLAB EDGE INSULATING

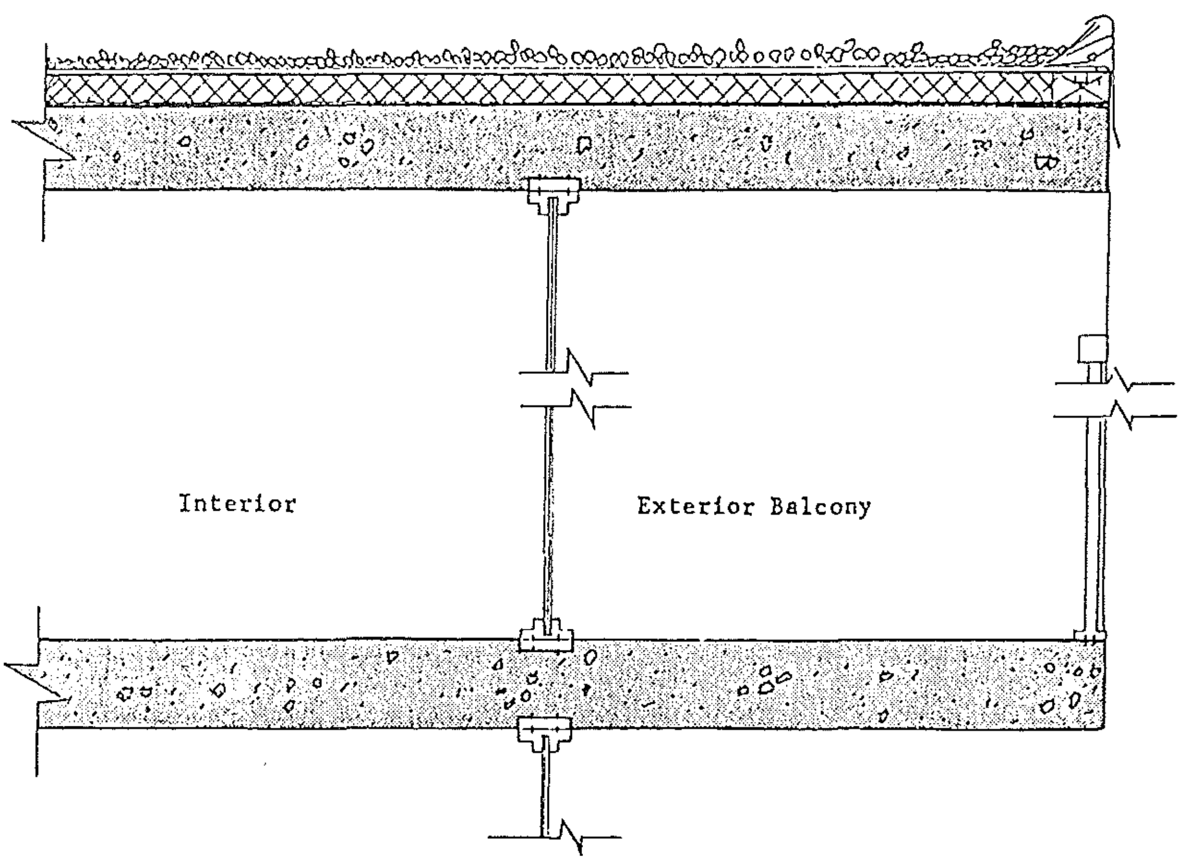

Figure 2

TYPICAL CONCRETE SLAB BALCONY OVERHANG