BUILDING PRACTICE NOTE

IMPROVEMENT OF AIRTIGHTNESS IN FOUR SCHOOLS

by

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ABSTRACT

Air leakage tests were conducted on four schools, before and after they were retrofitted, in order to determine the effectiveness of various measures for reducing leakage. Caulking wall joints will generally reduce air leakage and is worthwhile if the joints are accessible. Replacing leaky windows will also improve airtightness but may not be cost effective. Routine inspection of outside dampers of the air handling system can help ensure continued airtightness of schools.

INTRODUCTION

Since 1975, the Division of Building Research (DBR) has participated in a program of the Carleton Board of Education to reduce energy use in schools. One of the projects undertaken by DBR was to estimate the heating and cooling loads attributable to air infiltration in school buildings. To this end, air leakage measurements were made on eleven schools (Fig. 1)[1]. Additional tests were conducted on some of the schools to determine the contribution of the windows, doors and walls, and of the outside openings of the air handling systems, to the overall air leakage. On the basis of these tests, four schools (D, E, F and J) were selected by the School Board to be retrofitted for airtightness. A follow-up series of air leakage tests was conducted on the four schools by DBR to assess the effectiveness of the applied retrofit measures. The results of the follow-up tests are reported in this Note.

AIR LEAKAGE TEST METHOD

The air leakage characteristics of the four schools were determined using the fan pressurization method described in Reference 1. A large-vane axial fan was used to produce a negative pressure inside the building. The fan airflow could be adjusted between 0 and 23 m^3/s (0 to 50 000 cfm). The intake side of the fan was connected by several lengths of 0.9 m (3 ft) diameter ducting to a plywood panel that replaced an entrance door during the tests. The airflow rate was measured upstream of the fan intake: total pressure tubes were used to measure high airflow rates and an orifice plate to measure low airflow rates.

The reference pressure difference across the building enclosure was the average pressure differential across the exterior walls measured at the middle of each wall with a portable pressure meter.

The four schools were tested both with the air handling system in operation and with the system shut down, to permit comparison of leakage characteristics before and after retrofit, for both conditions. An additional test was conducted on School J with the air handling system shut down and all system openings to the outdoors sealed, in order to obtain the leakage characteristic of the exterior wall alone. This corresponds to a similar test conducted in the original series.[1]

RETROFIT MEASURES AND RESULTS

The original air leakage tests on the eleven schools were performed by DBR in 1976. Inspection of the schools, selection, and execution of retrofit measures in four schools were undertaken by the School Board between 1976 and 1980. The four schools, D, E, F and J, were retested by DBR in October 1980.

Since the retrofit measures in the four schools were not identical, each school is described separately. The descriptions of these measures were obtained from work order statements and from conversations with Board staff members. The quality of workmanship, therefore, could only be inferred by spot inspection of the schools. The following descriptions include some cost figures. These costs should not be used to evaluate the relative worth of the different measures taken, but should be looked upon only as a measure of the effort expended in each school.

Air leakage characteristics of the four schools, before and after retrofitting, are presented in Fig. 2.

School D

This single-storey school had the highest overall air leakage rate of the eleven schools originally tested. Investigation of the wall construction revealed many unsealed openings at the intersection of roof joists and exterior wall. Retrofit measures consisted of the following:

1. Polystyrene insulating boards (5 cm (2 in.) thick) were fastened to the inside surface of the exterior wall, between the suspended ceiling and the roof slab. An attempt was made to fit the boards around the joists.

2. Caulking was applied around the window frames but not around the insulating boards.

The total cost for the two measures was approximately $1300 for labour and materials. As indicated by Figs. 2 and 3, the leakage after retrofit was 73% of that recorded before, with the air handling system shut down. With the system operating leakage was reduced to 67% of that measured before. Unfortunately, the relative benefits of the two retrofit measures cannot be inferred from these results. Although the percentage reduction in leakage due to retrofit was large, this school still had a comparatively high leakage rate.

School J

This is a large open-plan building with an office and a gymnasium block attached to one corner. The ceilings in the office, and in corridors and vestibules were plastered. Classroom ceilings were plastered next to the exterior walls to cover the joints between wall and roof. Every exterior doorway was recessed inward from the plane of the exterior wall. The soffit over the doorway was an extension of the ceiling inside.

The previous study[1] showed that this school had very leaky exterior walls: nearly 81% of the total leakage occurred through the walls. Visual inspection revealed no obvious cracks or openings. A pressurization and smoke test, however, revealed air leaking out through numerous openings in the exterior block facade, and through the recessed light fixtures in the soffits over the doorways.

An attempt was made to caulk some of the joints in the exterior block facade, and to reduce leakage at the light fixtures by covering them up with metal plates. This effort at exterior sealing was not successful. Figure 4(a) compares the leakage characteristics of the wall alone between the 1976 and 1980 tests. The wall now registers slightly more leakage than before.

Inspection of the roof-top air handling units had revealed that one of the fresh air dampers was not closing properly, and this deficiency was corrected prior to the latest tests. The reduction in leakage shown in Fig. 4(b, c) can probably be attributed to the damper adjustment.

School E

The school consists of a two-storey classroom wing and a single-storey block containing the gymnasium and offices as well as classrooms. The exterior facade of the two-storey wing consists of steel wall panels set in aluminum framing. Aluminum windows are set in the steel panels. All joints between framing, panels and windows had been sealed with caulking compound at construction, nearly 20 years prior to the original tests.

The one retrofit measure undertaken in this school was to replace the defective caulking for the joints in the exterior facade (approximate cost $500). Fig. 5(a, b) indicates that leakage after the retrofit measure was approximately 70% of that before at the lower pressure difference. This also suggests that exterior sealing has a finite life, and should be replaced periodically as part of a maintenance schedule.

School F

This single-storey U-shaped building has a window-to-wall ratio of 30%. After the original test in 1976, School Board staff conducted air leakage tests on the windows and found that those in the west wall were especially leaky. At a cost of approximately $18 000, the thirty-two windows in the west wall were replaced. This represented approximately a third of the total windows in the school. Figure 6(a) indicates a 20% reduction in leakage with the air handling system off: Fig. 6(b) shows no apparent reduction with the system on. The window replacement program was influenced mostly by a need to replace windows that had deteriorated with time.

SUMMARY

Four schools received varying degrees of retrofit in an attempt to improve their airtightness. The lessons learned from this can be summarized as follows:

1. School D. Sealing of leakage openings between wall and roof joists, and between wall and window frames effected a significant reduction in leakage.

2. School J. Sealing ill-defined leakage openings on the exterior face of the walls did not result in any improvement. Repairs to a defective damper in the air handling system did, however, reduce air leakage.

3. School E. Sealing of defined leakage openings in the exterior facade did improve airtightness.

4. School F. Replacement of approximately one third of the windows with tighter ones did not reduce air leakage appreciably.

REFERENCES

1. Shaw, C.Y. and Jones, L. Air Tightness and Air Infiltration of School Buildings, ASHRAE Transactions, Vol. 85,1, 1979, pp. 85-95, NRCC 18030.

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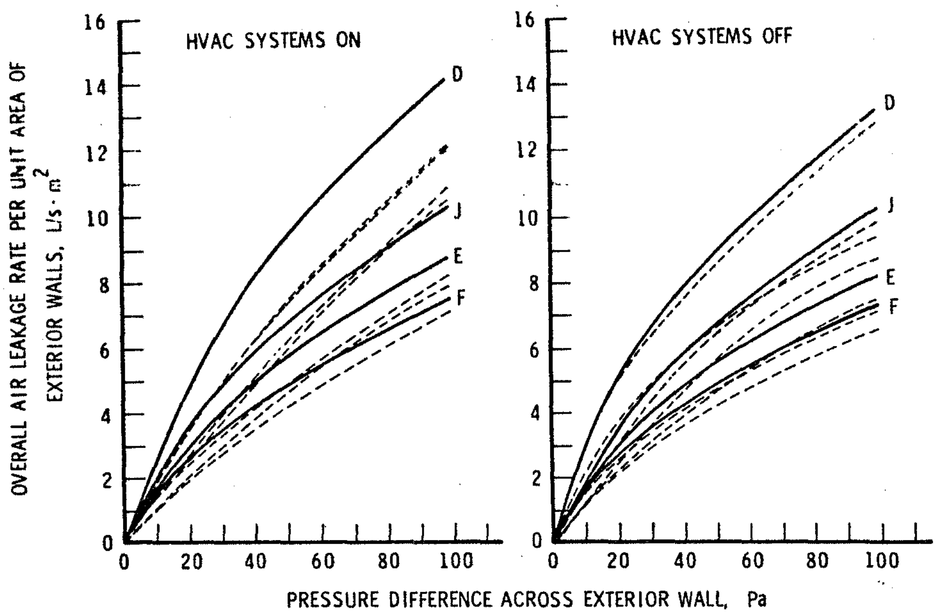

FIGURE 1

OVERALL AIR LEAKAGE RATES FOR SCHOOLS BEFORE RETROFIT

BR 6281-1

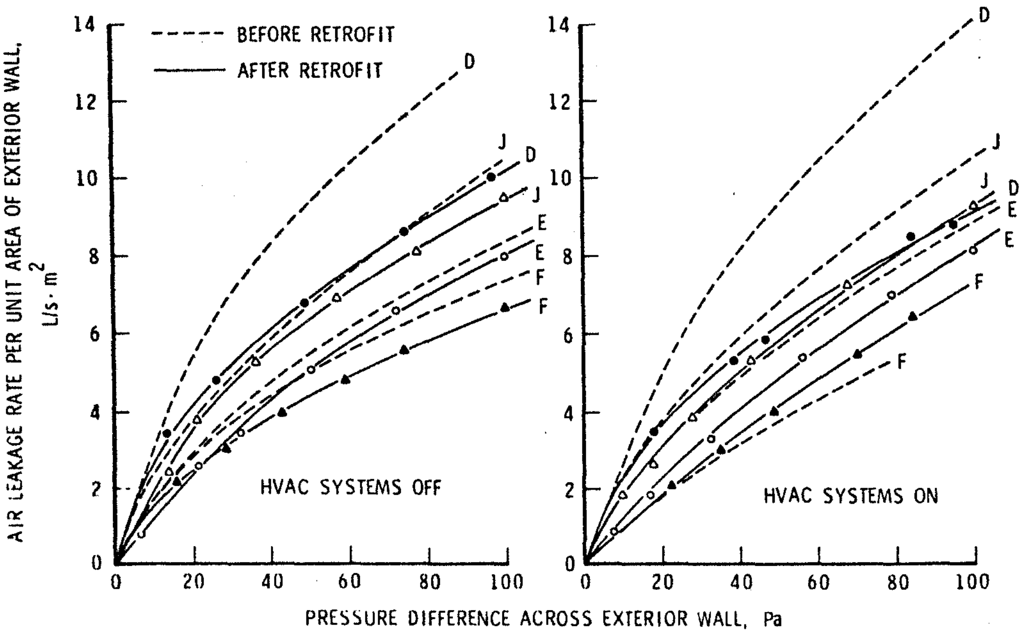

FIGURE 2

OVERALL AIR LEAKAGE RATES BEFORE AND AFTER RETROFIT

BR 6281-2

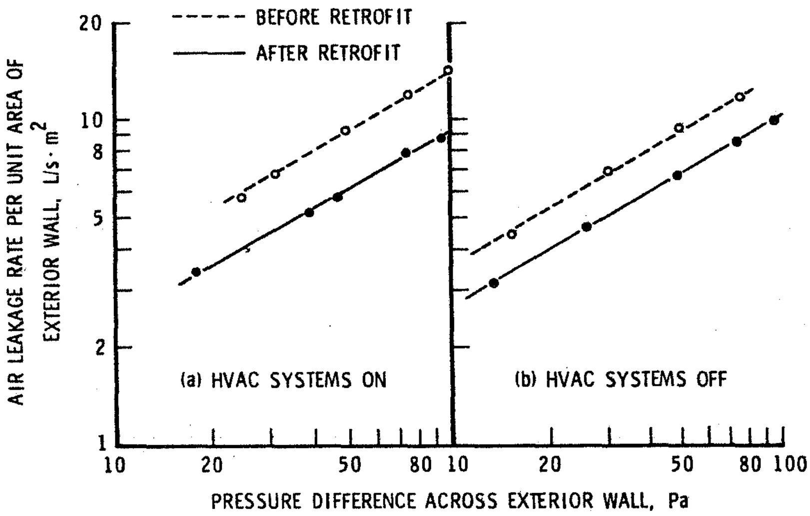

FIGURE 3

OVERALL AIR LEAKAGE RATES BEFORE AND AFTER RETROFIT FOR SCHOOL D

BR 6281-3

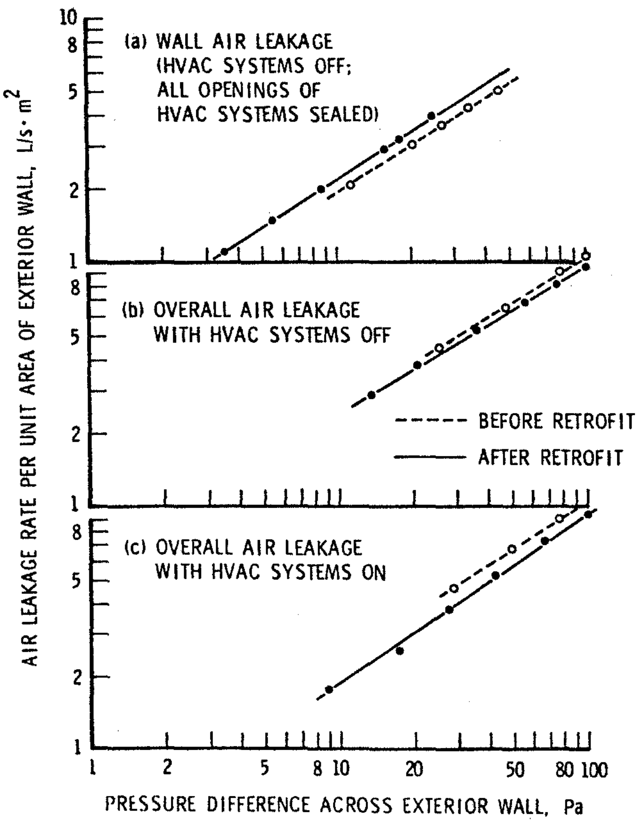

FIGURE 4

AIR LEAKAGE RATES BEFORE AND AFTER RETROFIT FOR SCHOOL J

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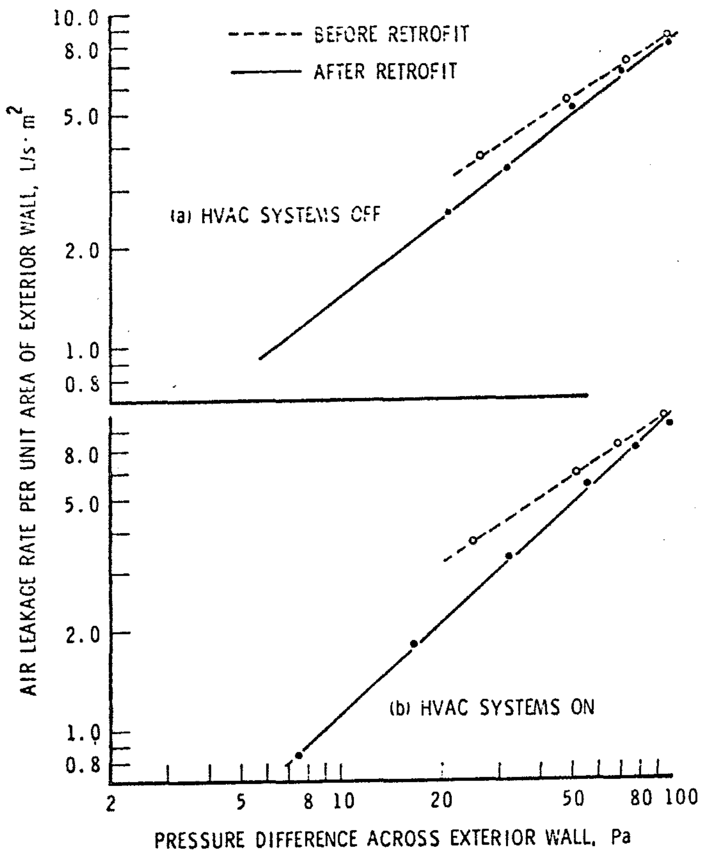

FIGURE 5

OVERALL AIR LEAKAGE RATES BEFORE AND AFTER RETROFIT FOR SCHOOL E

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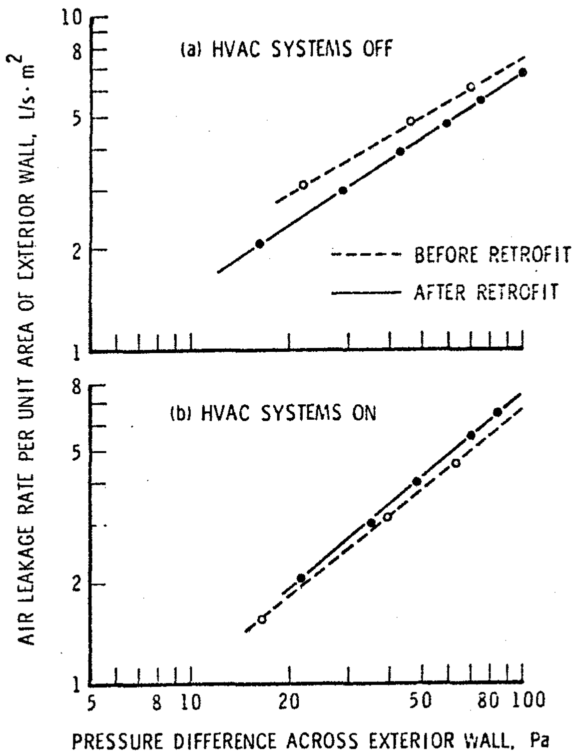

FIGURE 6

OVERALL AIR LEAKAGE RATES BEFORE AND AFTER RETROFIT FOR SCHOOL F

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