DYNAMIC BUFFER ZONE - CONTROLLING MOISTURE AND HEAT FLOW

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ABSTRACT

The building envelope is primarily an environmental separator, which allows indoor spaces to be maintained at different conditions from the outside environment. Intentional humidification during the heating season is a common practice in cold climates. Moisture escaping from a humidified building due to air leakage through flaws in the air barrier system can negatively affect the durability of the building envelope. Hence, an effective air barrier is an essential component of any building envelope exposed to large condensation potentials.

The Dynamic Buffer Zone (DBZ) performs the function of the air barrier and can act as dynamic insulation in a building envelope. The DBZ system creates conditions in an existing or purpose built air space (DBZ cavity) located within an exterior wall that effectively separates the interior and the outdoor environments. Conditions within the DBZ cavity that need to be controlled are air pressure, moisture content, and temperature.

To effectively prevent exfiltration of humid interior air through the building envelope during cold weather, the air pressure of the DBZ cavity is maintained slightly higher than the interior air pressure. Theoretically, the cavity air pressure needs only to be nominally higher than that of the interior space to prevent air leakage from the interior. During winter conditions, outdoor air will have a low moisture content which makes it an ideal air supply for the DBZ cavity. The requirements for pressurization of the DBZ cavity will ensure that interior humid air will not leak outwards into the building envelope. If any leakage of air from the DBZ cavity to the outside occurs, the low moisture content of the DBZ air will eliminate the threat of condensation within the building envelope.

When utilizing the DBZ cavity as an air barrier or as a dynamic insulation system, it is desirable to minimize the amount of heat that is initially added to the incoming outdoor air. Dynamic insulation can reduce the cost associated with initial heating by allowing the DBZ air to capture some of the heat that would otherwise have been lost to the exterior environment.

This paper will discuss the DBZ and its uses in cold climates. The fundamental principles governing the DBZ will be presented. The different modes of operation will be discussed, addressing constructability, both in new and retrofit applications. Finally, case studies will be presented, addressing the installation of the DBZ in both a restoration and new construction application.
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KEYWORDS

Exterior Wall, Dynamic Buffer Zone, Air Leakage, Moisture

AIR BARRIERS AND HIGH HUMIDITY ENVIRONMENTS IN COLD CLIMATES

Intentional humidification during the heating season is a common practice in many cold regions for reasons that may include human comfort, operation of electronic equipment, and the control of dimensional changes of materials due to fluctuation in relative humidity. Furthermore, buildings such as hospitals, libraries, museums and swimming pools demand greater interior humidity levels as compared to typical office buildings. An important environmental factor that needs to be considered when evaluating the suitability of a building envelope design that is subjected to cold weather is the interior relative humidity. Moisture escaping the interior building environment can have serious detrimental effects on the durability of the exterior walls and roof comprising the building envelope.

Accordingly, the successful performance and durability of building envelopes in cold climates is significantly affected by their ability to control moisture movement. It has been established that the air barrier is an essential component of any durable building envelope. This is not only true for new construction, but also for retrofits of existing structures, especially for those masonry structures where the existing envelope was not designed to control the current standards for high interior humidity. Many existing masonry buildings such as commercial and industrial buildings have stood the test of time remaining in excellent shape for many decades. This is attributed not only to the use of appropriate materials and construction practices, but also to the interior environment to which the building envelope was exposed. The interior spaces were not intentionally humidified and would rarely have a relative humidity above 10% during the coldest months [1]. Furthermore, the placement of steam heating systems within the building envelope, and the lack of insulation within the envelope ensured that sufficient amounts of heat would penetrate the masonry wall to remove any moisture that may have entered the building envelope.

Design deficiencies and construction imperfections have proven that the conventional design and construction of air barrier systems in new buildings, in many instances, does not provide sufficient air leakage control for high humidity environments. With building envelope retrofits, the potential occurrence of air leakage is compounded by the large number of joints and protrusions, which can make the installation of a continuous air barrier system difficult and expensive to install. The Dynamic Buffer Zone method of air leakage control can overcome such difficulties in both new and retrofit construction.

DYNAMIC BUFFER ZONE CONCEPT

The development of the Dynamic Buffer Zone (DBZ) system is attributed to the late Kirby Garden, a researcher at the National Research Council of Canada. The system is based on the concept of intentionally controlling conditions in an air space between the indoor environment and the outdoors. Those conditions of the air inside the airspace that need to be controlled are temperature, moisture content and air pressure. As the cavity air pressure is kept slightly greater than the interior air pressure, this buffer zone prevents the deleterious effects of excessive moisture in the exterior wall by essentially eliminating the leakage of moist air from the interior. To be effective, the air used to pressurize the cavity must have a low moisture content. Using tempered outdoor air during cold weather will ensure that the moisture content of the air is low.

A fan is required to introduce the air into the cavity from the exterior and a source of heat is necessary to pre-heat the incoming DBZ air. To ensure that the size of both the fan and the heat source are minimized, the interior finish that forms the inside boundary of the cavity should be reasonably well sealed at all intersections with ceilings, window frames, columns and other intrusions. Furthermore, the existing wall forming the exterior boundary of the cavity also should be reasonably air tight to reduce the DBZ air flow that is required to pressurize the cavity. Air pressure and humidity sensors that communicate with the building HVAC system must be installed is strategically selected positions within the DBZ cavity to ensure that the system is operating as required.

The DBZ system can be operated in two modes. The first mode is known as a ‘balloon’ or pressure controlled system where air is pumped into the cavity on an as need basis ensuring that the cavity pressure remains greater than the interior space pressure. The second mode is known as an 'exhaust' system. This system is based on providing a continuous flow of air through the DBZ cavity by intentionally exhausting air from the cavity while ensuring that the air pressure within the cavity is maintained above that of the interior space.

In addition to walls and roofs, the DBZ system can also incorporate windows to provide additional thermal comfort and condensation control by increasing the window surface temperatures and thus allow higher indoor humidity. This system will also eliminate the need for convective units used to prevent cold drafts below windows.

However, one must be aware of any hazardous materials in the walls proposed for the DBZ such as asbestos or mould especially when dealing with the retrofit of existing buildings since causing the said contaminates to become air borne can have serious consequences.

It is the exhaust mode of operating the system which imparts a great deal of versatility to the DBZ system as it can promote drying of the exterior wall following the occurrence of rain penetration, allow air borne contaminants to be contained in an interior space and controlled, and increase the temperature of interior finishes of the exterior wall by supplying DBZ air that is above the indoor air temperature. This last attribute will eliminate 'drafts' associated with wall that are not insulated and increase thermal comfort.

There is a further advantage of the exhaust system that typically has not been fully exploited. By controlling the flow rate and the initial temperature of the DBZ air, the DBZ system can act as both an air barrier and as a dynamic insulation system that can provide greater thermal efficiencies when compared to the same envelope without airflow.

DBZ DUAL FUNCTION - DYNAMIC INSULATION

Dynamic insulation systems have been rigorously investigated in many European countries since the 1970's. A dynamic insulation system consists of a heat-carrier fluid, such as air, being circulated by natural or mechanical means through an air cavity or through permeable thermal insulation in a building envelope. This system causes the once static building envelope to act as an air-to-air heat exchanger reducing the thermal load or improving the comfort conditions of the indoor space [2]. The moving air stream through the air cavity or the insulation absorbs some of the heat that would be conducted through the static building envelope.

In regard to the DBZ, during winter conditions the outdoor air used for the DBZ wall cavity will be introduced into the cavity at a temperature lower than the indoor temperature. Consequently, the air stream will capture heat that would otherwise be lost to the outdoors. The effectiveness of this dynamic insulation system is dependent on what happens to this heated air once it has been exhausted from the wall cavity. The first option is to combine the exhaust DBZ air with the building's ventilation air if the DBZ cavity is free of contaminants that could cause odour or respiratory problems. Alternatively, if there is sufficient airflow, the exhaust DBZ air could constitute all of the ventilation requirements for the building. The second option is to exhaust the cavity air to an energy recovery unit such as a heat pump. The recovered heat can be used either as an auxiliary heat source for ventilation air or the hot water system.

The thermal efficiency the DBZ dynamic insulation system would be sensitive to factors related to construction such as:

1. The exterior side of the cavity should be as airtight as possible to maximize the recovery of heated air, especially because the cavity will be pressurized, and

2. Irregularities in the flow path of the air, such as stagnation areas or short circuits, will reduce the amount of heat recovered by the airflow.

DBZ, A RETROFIT APPLICATION - CANADA LIFE ASSURANCE BUILDING

The Canada Life Assurance Headquarters building located in Toronto, Canada was to undergo interior renovations in the mid-1990s. This building was originally constructed in ca. 1930 and is historically designated. It is 17 storeys tall and the exterior walls were uninsulated and were constructed of non-load bearing masonry generally consisting of limestone cladding secured to a brick back-up (Refer to Figure 1). An integral part of the proposed renovations included the intentional humidification of the interior space to 35% relative humidity during the heating season it was recognized that the upgrade of the mechanical systems would produce interior levels of humidification and pressurization that likely would have an adverse effect of the durability of the exterior walls because of the potential for moisture accumulation within the exterior wall fabric.

Figure 1 - 330 University Avenue, Toronto, Ontario – Canada Life Assurance Head Office retrofitted with DBZ.

Following the evaluation of possible retrofit alternatives, it was decided that the DBZ strategy would be the best approach to sustain and protect the exterior walls by essentially recreating the micro-climate the walls had been experiencing since original construction.

The pressure controlled type DBZ system was utilized for this project. The existing induction unit risers were utilized to deliver the dry tempered air to the DBZ cavity, which consisted of primarily a new cavity constructed with steel studs or an existing cavity between the original plaster finish and the clay tile back-up (Refer to Figure 2). This existing cavity typically was used where the interior plaster finishes were historically designated.

The DBZ system was chosen as the most viable retrofit option and was implemented 1995/96. Although the DBZ system is effective in the control of moisture movement through a building envelope, if not constructed properly, as with any technology, it may not be effective. Consequently, a monitoring program was commissioned in 1999 to verify that the DBZ system was indeed effective in controlling moisture migration into the exterior walls.

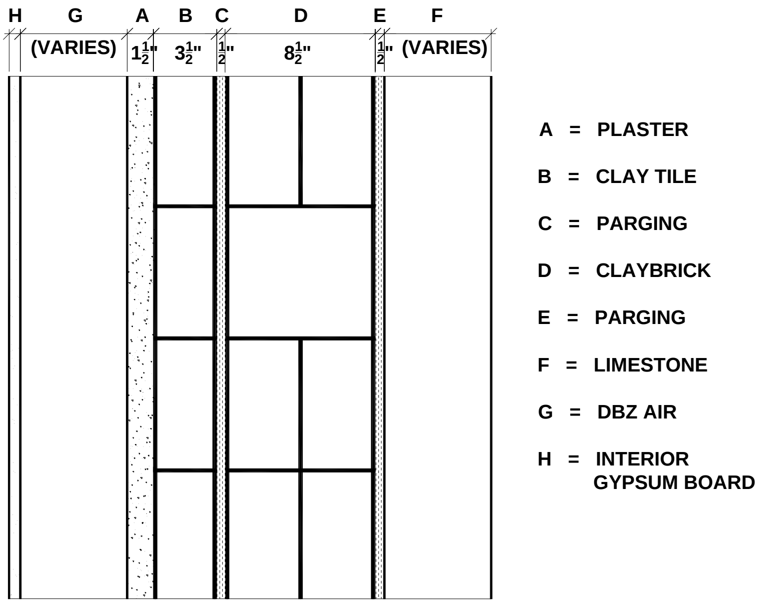

Figure 2 - General wall configuration incorporating the DBZ. Note that many different wall conditions existed.

To evaluate the performance of the DBZ system, isolated sections of the system were investigated on the 2nd, 10th, 13th and 17th floors. Portable data loggers and remote electronic sensors were utilized at each of the monitoring stations to measure the following: interior air space temperature, Interior relative humidity, DBZ air temperature, DBZ relative humidity, DBZ cavity pressure, Exterior air temperature, and Exterior relative humidity.

The monitoring schedule was designed to demonstrate how the moisture content of the DBZ cavity responded to the operation of the DBZ system. A typical monitoring period consisted of maintaining specified interior temperature and relative humidity conditions for six (6) days. During the first and last forty-eight (48) hours of this monitoring period, the DBZ system was in operation and maintaining an average DBZ cavity pressure of approximately 5 Pa relative to the interior space.

For the remaining forty-eight (48) hours, the DBZ system was turned off. Temperature, relative humidity and pressure readings were taken hourly for the duration of the monitoring period. The target interior space temperature and relative humidity were 22 °C and 35%

respectively. Also, the DBZ supply air temperature was maintained at 15 °C. During the testing, the exterior temperature typically was between -5°C and 0°C.

Findings

Figure 3 depicts the monitoring results for the DBZ locations tested on the 13th floor. As the Figure demonstrate, during the periods when the DBZ fan was in operation, the DBZ air moisture content correlated very well with the exterior air moisture content. Also, when the DBZ system was turned off, the moisture content of the air within the DBZ cavity increased such that the cavity moisture content became greater than that of the exterior air and approached the interior air moisture content. The results observed on the 13th floor were consistent with the other monitoring stations. The response observed of the DBZ cavity's moisture content to the operation of the DBZ system is consistent with the expected performance of the DBZ.

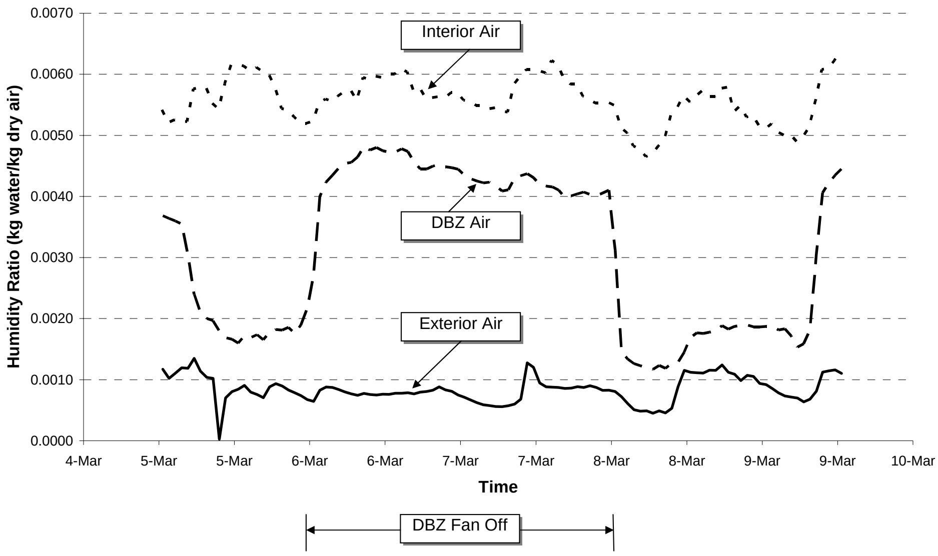

Figure 3 - DBZ monitoring results for the thirteenth floor.

DBZ, NEW CONSTRUCTION APPLICATION - MEDICINE HAT PERFORMING ARTS AND HERITAGE CENTRE

Located in downtown Medicine Hat, Alberta Canada, within walking distance of all cultural and business amenities, will be the home of the 13,000 m^2 Medicine Hat Museum, Art Gallery, Archives and Administration building, and a new 700-seat performing arts center that will offer a wide range of programs, services, and activities (Refer to Figure 4). The design of the exterior walls required an innovative scheme in order to deal with the high interior relative humidity demanded by the artifacts of the Art Gallery and Museum coupled with the frigid cold temperatures endured during the winter months.

The museum/gallery areas are required to maintain 21°C and 50% relative humidity throughout the year including the heating season when the temperatures are commonly below -25°C and can get as low as -40 °C. During the preliminary design stage, various exterior wall assemblies were discussed with specific focus on the air/vapour retarder systems because of the demanding service environment. The exterior cladding for the museum was to consist of clay brick in a veneer construction. Although the final wall design resembles a conventional vented masonry wall, it was the opinion of the design team that the convention sheet air barrier system included could provide complete protection against air exfiltration. As such, the exhaust type DBZ system was incorporated in the exterior walls of the museum/gallery (Refer to Figure 5). The exhaust type DBZ system was chosen as it was regarded as more cost effective strategy since the exhaust air would be utilized to supplement the parking garage air (as described below) as opposed to allowing the air to leak out of the wall.

Figure 4 - Medicine Hat Performing Arts and Heritage Centre
Architect: Diamond and Schmitt Architects Inc.
Associate Architect: The Cohos Evamy Partners
Mechanical and Electrical Engineers: Crossey Engineering Inc.
Structural Engineers: Yolles Partnership Inc

The exterior wall in which the DBZ was incorporated is approximately 131 m long and 8.5 m high. The Mechanical Consultant, Crossey Engineering, opted to introduce the DBZ air at the top of the wall through a series of ducts and exhaust the air at the bottom of the wall through a series of holes in the concrete floor slab into a concrete duct located in the parking garage. Since the DBZ air cannot be exhausted directly into the parking garage because of code restrictions, the air is exhausted to the exterior of the fresh air intake for the garage where it will be sucked into the make-up air handling unit for the garage. To permit proper control of the DBZ air pressure, the mechanical consultant decided to incorporate both a supply and exhaust fan.

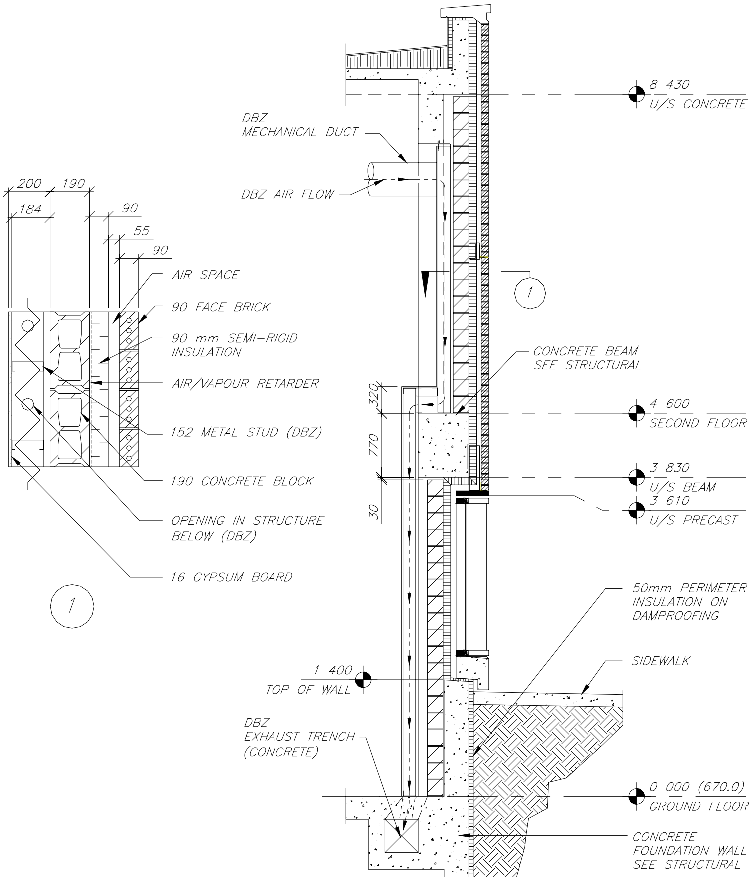

Figure 5 - Typical DBZ wall configuration for the Medicine Hat Cultural centre.

CONCLUSION

The DBZ system provides a flexible building envelope system that can be altered to accommodate changes in the interior environment. Although the context for the application of the Dynamic Buffer Zone system thus far has focused on the retrofit of masonry buildings, there exists a wide-spread potential for its application in a variety of retrofits and in new construction. Specialty facilities such as hospitals, museums, indoor swimming pools and tropical exhibits in cold climates that need high indoor humidity and consequently are at high risk of moisture damage are ideal candidates for the DBZ system. The configuration of the DBZ system employed is dependent on the design teams understanding of the project goals. But in the case of a retrofit, a thorough understanding of the limitation imposed by the existing conditions of the building also is required.

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