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The Freeze-Thaw Cycle in Concrete and Brick Assemblies

Introduction

The freeze-thaw cycle is a major cause of damage to construction materials such as concrete and brick assemblies. Freeze-thaw damage occurs when water fills the voids of a rigid, porous material and then freezes and expands. The volume of frozen water is 9% greater than liquid water, so when water freezes pressure is exerted on the surrounding material, and when the pressure exceeds the tensile strength of the material, cracks will result. During this process, the voids are enlarged, enabling the accumulation of additional water during the next thaw; this results in additional cracking during the next freeze. Substantial damage can occur over subsequent freeze-thaw cycles.

The NIH Bethesda campus, like many parts of the US, is in an area prone to freeze-thaw damage. The average high and low temperatures in January are 44^0 and 29^0F, so freezing and thawing can occur frequently. This kind of recurrence makes the cycle more destructive than in colder climates, which remain below freezing for much of the winter and therefore experience the freeze-thaw cycle less frequently.

Freeze-Thaw Damage

Freeze-thaw damage is caused by excessive water on the surface of or within assemblies. The two types of damage are surface spalling and internal cracking.

Surface spalling is a result of recurring accumulation of water or snow on surfaces, both horizontal and vertical, causing them to remain wet for extended periods to time. During freezing, the external layer of material fractures to the depth of water penetration and falls off. Concrete surface spalling results in the exposure of underlying aggregate; repeated spalling can expose reinforcing bars, leading to further deterioration. Brick surface spalling results in the flaking of the outer layer of brick, exposing the inner layers which are typically softer, more porous, and more susceptible to further freeze-thaw damage.

Internal cracking occurs when internal cracks and voids are filled with water and subject to freezing. Unlike surface spalling, the cracking starts on the interior, which may not be evident to visual inspection. Upon further freeze-thaw cycles, the damage may propagate to the surface.

Prevention of Freeze-Thaw Damage

Both surface spalling and internal cracking are progressive, with damage that will increase in severity if not corrected, making them issues that are better handled proactively than reactively. There are numerous strategies for preventing damage, including the following:

Control rain, ice, and snow penetration. One way to prevent freeze damage is controlling environmental water. Properly detailed parapets, copings, roof edges, and other critical connection points prevent water penetration in assemblies. Overhangs, drip edges, and other details prevent water from saturating wall suraces. Details by SMACNA (Sheet Metal and Air Conditioning Contractors National Association) or other recognized industry sources that are not overly reliant on sealant or maintenance should be used.

Control groundwater. Eliminate capillary action from damp ground. Earth should be well drained and slope away from the structure, and assemblies should have flashing or other methods of reducing water from being drawn up into wall assemblies.

Use water-resistant brick. Use bricks appropriately graded for resistance to freezing damage. Grade SW (severe weathering) brick is intended for use where high and uniform resistance to cyclic freezing is desired and where the brick may be frozen when saturated with water. Grade MW (moderate weathering) brick is intended for use where moderate resistance to cyclic freezing damage is permissible or where the brick may be damp but not saturated with water when freezing occurs.[2]

Use appropriately designed concrete. Concrete should be designed with characteristics that will minimize freeze-thaw damage. A low water to cement ratio reduces permeability, which will in turn reduce both surface and internal water absorption. High strength concrete (6,000 psi or greater) has increased tensile strength and will withstand increased internal pressures caused by freezing. Air-entrained concrete (4% or more of concrete volume) contains microscopic bubbles which allow the concrete to expand with less likelihood of cracking. Smaller aggregate is less likely to have internal voids than large aggregate.

Conclusion

The freeze-thaw cycle is a concern in most climates and should be addressed during design. With proper detailing and specification freeze-thaw damage to assemblies can be reduced or eliminated.

References

[1]ASTM C216, Standard Specification for Facing Brick (Solid Masonry Units Made from Clay or Shale)

[2]Brick Industry Association, Technical Notes 9A, Specification for and Classification of Brick