Understanding Windbreak Principles

Required height and length for typical placements may surprise you

by Bruce A. Suprenant and Ward R. Malisch

Documents published by ACI and other industry organizations recommend erecting temporary windbreaks (Fig. 1) to reduce the evaporation rate in fresh concrete and thereby minimize the occurrence of plastic shrinkage cracking. None of the documents, however, describe the windbreak height, porosity, length, orientation, or continuity needed to reduce wind speed to a benign level. Without such information, it’s difficult to determine if windbreaks comprise an economical and effective strategy for reducing the evaporation rate.

Benefits of Reducing Wind Speed

Surface drying of fresh concrete is initiated whenever the evaporation rate is greater than the bleeding rate: the rate at which water rises to the surface of recently placed concrete. High concrete temperatures, high wind speed, low air temperatures, low relative humidity, or a combination of these can cause rapid evaporation of surface water.

ACI 305R-10 indicates that the probability of plastic shrinkage cracking increases whenever the environmental conditions increase evaporation or when the concrete has a low bleeding rate. It also indicates that experience in limiting plastic shrinkage cracking has led to specified allowable evaporation rates from 0.05 to 0.2 lb/ft²/h (0.25 to 1.0 kg/m²/h).

Evaporation rates can be estimated using a nomograph published in References 1 and 4, with the wind speed, one of the most important variables, measured at an elevation about 20 in. (0.5 m) above the top of the concrete slab. For example, with a relative humidity of 50%, an air temperature of 80°F (27°C), and a concrete temperature of 80°F (27°C), reducing the wind speed from 15 mph (24 km/h) down to 5 mph (8 km/h) reduces the evaporation rate from 0.2 to 0.1 lb/ft²/h (1.0 to 0.5 kg/m²/h).

The effect of a windbreak on a concrete placement is shown schematically in Fig. 2, with bleeding and evaporation plotted as functions of time after placement. A critical point...
occurs when evaporation exceeds bleeding before the time of setting. In many placements, critical points occur very soon after placement, when bleed water has not yet reached the surface, and shortly before the time of setting, when the bleeding rate of the mixture slows. The concrete may endure the first critical zone because the mixture is plastic enough to simply shrink into a thinner placement and finishing operations will close incipient cracks, but the second critical zone could cause damage. The example shows that a significant reduction in evaporation rate (in this case, obtained with a windbreak) has the potential of eliminating both critical zones.

**Windbreak Function**

For over a century, the effects of windbreaks (shelterbelts and fences) have been studied for their effects on local and microclimates. These studies show that the height, porosity, length, orientation, and continuity of a windbreak are key factors that affect the wind speed in the sheltered zone downwind of the windbreak.

**Height**

Windbreak height \( H \) is the most important factor determining the area protected downwind. The flow pattern resulting from a windbreak is illustrated schematically in Fig. 3. The region of disturbed flow downwind of the windbreak is divided into two zones: the wind shadow and the remainder of the wake. The former, an area with an eddying flow, is generally about 10 to 15\( H \) downwind. Incident flow is reestablished about 40\( H \) downwind. Measurements show that the near-surface wind speeds behind a solid windbreak will be at or below 50% of the open-field wind speed only within a distance of 7\( H \) downwind (Fig. (4a)). Therefore, an 8 ft (2.4 m) tall solid windbreak will reduce a 20 mph (32 km/h) wind to about 10 mph (16 km/h) within a shielded area limited to only about 55 ft (16 m) from the barrier.

**Porosity**

If the windbreak is porous, air bleeding through it will increase the pressure immediately adjacent to the downwind face. Increasing the porosity moves the position of the minimum wind speed leeward and the width of the protected area will increase. As can be seen in Fig. 4(c), the greatest protection is provided by the barrier with 40% porosity. Wind speeds behind a windbreak with 40% porosity will be at or below 50% of the open-field wind speeds within a distance of about 10\( H \) downwind (Fig. (4(c))), so an 8 ft (2.4 m) tall windbreak will reduce a 20 mph (32 km/h) wind to about 10 mph (16 km/h) within a shielded area of about 80 ft (24 m) from the barrier.
wind speeds of 40 to 60% of open-field wind speeds are summarized in Table 1.

Orientation, length, and gaps
To be most effective, a windbreak must be perpendicular to the wind direction. Also, the length of a windbreak must exceed the length of the intended protected area—not only because wind directions shift, but eddies at the ends of windbreaks can increase local wind speeds and reduce the protected area. Figure 5 shows the protected areas created by one- and two-legged windbreaks with winds blowing in different directions. Obviously, a shift in wind direction could render a one-legged windbreak useless. Although a two-legged windbreak will help avoid this problem, the protected area is still limited. Creating a full-perimeter windbreak will provide the most reliable (and expensive) protection. Gaps will cause locally high wind speeds, so openings required for access should be located on the downwind face only.

Applications for Concrete Placements
The application of windbreaks varies depending on the concrete placement type:
- Slab-on-ground;
- Elevated slab; and
- Topping slab.

Slab-on-ground
Concrete slab-on-ground placements are usually strip or block placements that range in size from about 10,000 to 30,000 ft² (900 to 2800 m²). Strip placements are usually in width increments of column spacing (bays) and lengths of five to 10 bays. Thus, for a typical 30 ft (9 m) column spacing, concrete strips would be 30 ft (9 m) wide and up to 300 ft (90 m) long. Contractors might place one, two, or three strips in one concrete placement, resulting in total placement areas of 9000, 18,000, or 27,000 ft² (850, 1700, or 2500 m²).

Based on Fig. 4 and Table 1, to reduce the wind speed by 50% everywhere on a concrete placement of width \( W \), the solid windbreak height \( H \) would need to be \( \frac{W}{7} \). So, for a 30 ft (9 m) wide strip placement, \( H \) would need to be about 4 ft (1.2 m).

Assuming the wind will blow only across a strip placement, the length of a one-legged windbreak needed to protect the placement will be the placement length plus two placement widths \((L + 2W)\). Table 2 shows the windbreak requirements for windbreak to reduce wind speed by 50% over entire strip placement width.

Table 1: Windbreak heights required for specific wind reductions for windbreaks with various porosity (based on Fig. 4)

<table>
<thead>
<tr>
<th>Windbreak type</th>
<th>Leeward wind speed, % of open-field wind speed</th>
<th>Required windbreak height ( H ) as a function of protected zone width ( W )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solid</td>
<td>40: ( \frac{W}{4} )</td>
<td>50: ( \frac{W}{7} )</td>
</tr>
<tr>
<td></td>
<td>60: ( \frac{W}{13} )</td>
<td></td>
</tr>
<tr>
<td>20% porous</td>
<td>40: ( \frac{W}{4.5} )</td>
<td>50: ( \frac{W}{6} )</td>
</tr>
<tr>
<td></td>
<td>60: ( \frac{W}{13} )</td>
<td></td>
</tr>
<tr>
<td>40% porous</td>
<td>40: ( \frac{W}{8} )</td>
<td>50: ( \frac{W}{10} )</td>
</tr>
<tr>
<td></td>
<td>60: ( \frac{W}{12} )</td>
<td></td>
</tr>
<tr>
<td>60% porous</td>
<td>40: ( \frac{W}{7} )</td>
<td>50: ( \frac{W}{8.5} )</td>
</tr>
<tr>
<td></td>
<td>60: ( \frac{W}{11} )</td>
<td></td>
</tr>
</tbody>
</table>

Table 2: Requirements for windbreak to reduce wind speed by 50% over entire strip placement width

<table>
<thead>
<tr>
<th>Concrete placement: ( W \times L ), ft (m)</th>
<th>Placement area, ft² (m²)</th>
<th>Windbreak height, ft (m)</th>
<th>Windbreak length, ft (m)</th>
<th>Total Windbreak area, ft² (m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>One strip: 30 x 300 (9 x 90)</td>
<td>9000 (850)</td>
<td>4 (1.2)</td>
<td>360 (110)</td>
<td>1440 (132)</td>
</tr>
<tr>
<td>Two strips: 60 x 300 (18 x 90)</td>
<td>18,000 (1700)</td>
<td>8 (2.4)</td>
<td>420 (130)</td>
<td>3360 (312)</td>
</tr>
<tr>
<td>Three strips: 90 x 300 (27 x 90)</td>
<td>27,000 (2500)</td>
<td>12 (3.6)</td>
<td>480 (150)</td>
<td>5760 (540)</td>
</tr>
</tbody>
</table>
height, length, and area required for placement widths of 30, 60, and 90 ft (9, 18, and 27 m). Values are rounded down to the nearest 1 ft.

A schematic of the 30 ft (9m) placement (Fig. 6) shows the relative scale of the windbreak. Whether temporary plywood fencing or polyethylene sheeting attached to dimension lumber frames are used, the cost will be significant, depending on the ability to move and reuse the windbreak.

Fig. 6: To reduce wind velocity by 50% over a 30 ft (9 m) wide protected zone, a 4 ft (1.2 m) high windbreak is needed. To protect a 30 x 300 ft (9 x 90 m) concrete strip placement, a one-legged windbreak must be 360 ft (110 m) long

Fig. 7: To reduce wind velocity by 50% for a 150 x 150 ft (46 x 46 m) block placement, a windbreak must be 20 ft (6 m) high. Two 300 ft (90 m) long legs will provide the needed protected area, but at a very high cost

Windbreaks for block placements are even less economical than windbreaks for strip placements. For example, consider a 150 x 150 ft (46 x 46 m) slab-on-ground concrete placement protected with a two-legged windbreak (Fig. 7). In order to achieve a 50% reduction in wind speed, the windbreak would need to be over 20 ft (6 m) tall. The length of each leg of the windbreak would need to be 300 ft (90 m), so the total windbreak area would be at least 12,000 ft² (540 m²). A 20 ft (6 m) tall windbreak would be particularly costly, given that the design wind speed for a temporary barrier could be as high as 75% of the basic wind speed required for the design of a permanent structure.

Elevated slab

While perimeter safety fencing is common for elevated construction, its height is generally limited to 4 ft (1.2 m), so wind protection will be limited. The windbreak requirements for elevated concrete placements on reinforced concrete frames are similar to those for slabs-on-ground, except the windbreaks need to be positioned above ground. Because of the increased costs for labor and equipment to transport materials and erect them, these windbreaks would be even less economical than those for a slab-on-ground.

Enclosed topping slab

Windbreaks for topping slabs placed on metal deck or precast members can be created by using wood and plastic sheathing around the building perimeter at each floor. This type of windbreak effectively eliminates the wind and is less expensive to construct than other standing windbreaks. Windbreaks for this type of concrete placement may be economical, particularly when they also serve to enclose cold weather concreting operations.

Windbreaks May Be Impractical

Industry recommendations for windbreaks appear to have originated in the early 1940s and 1950s, when concrete placements were relatively small and evaporation reducers were not available. Windbreaks may be practical for small placements, but their construction may not be feasible for large strip or block placements of slabs-on-ground or for some elevated slabs.

One alternative is to use ride-on finishing machines equipped with containers holding evaporation reducers—solutions of organic chemicals in water that form a film over the bleed-water layer and reduce the rate of bleed-water evaporation.1 As Section 5.10 of ACI 302.1R-0410 indicates, evaporation reducers “...can be sprayed on the plastic concrete one or more times during the finishing operation...” Another alternative is a spray-on concrete finishing aid that does not retard evaporation but acts similar to water-reducing agents that break up cement flocs. This product is worked into the surface, freeing water trapped within the cement flocs and reducing the likelihood of plastic shrinkage cracking.
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References
2. ACI Committee 302, “Guide for Concrete Floor and Slab Construction (ACI 302.1R-04),” American Concrete Institute, Farmington Hills, MI, 2004, p. 63.

Selected for reader interest by the editors.