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## Shotcrete Rebound— How Much is Enough?

By Michael Ballou

**R**ebound is an essential element in the application of shotcrete. Rebound is defined as follows: “Mainly large aggregate with some sand and cement that bounces or ricochets off the receiving surface and falls on to lower surfaces.”<sup>1</sup> There is a vital function that is achieved in the rebounding of shotcrete. The secret lies in knowing how much rebound is enough.

To paint a mental picture for the reader to understand rebound, consider a baseball. If you take a baseball and dip it into some fresh concrete and pull it out, it will be covered with mortar—a paste consisting of the cement and fine aggregate and water—that acts as the glue required to create an artificial rock called “concrete.” If you took this baseball covered with mortar and threw it at a high velocity against a solid block wall at a 90-degree angle to the wall, the ball would strike the surface and bounce off. Because the paste is also in motion at 95 miles per hour and the paste is not securely bonded to the ball, some paste will leave the surface of the baseball, contact the wall, and adhere to the surface. In layman’s terms, it would “splat” onto the wall. The harder the baseball is thrown, the more the paste would leave the surface of the ball and stick to the wall. As you might guess, if

the same ball is thrown at the wall at a slower speed, the ball would still bounce off, but only a small portion of the paste would stick to the wall. The paste would not be forced into the pores of the wall. It would either strike the wall and fall to the ground or stay on the baseball.

What would happen if you kept throwing a mortar-covered ball repeatedly at the wall? There would be a layer of mortar accumulating on the wall. Eventually, the ball would also embed itself into the mortar and stay on the wall.

What if the baseball is thrown at an angle to the surface of the wall, not perpendicularly? The ball would still bounce off, but there would be even less mortar transferred to the wall. The ball would not become embedded on the surface. It is only by throwing the ball perpendicular to the wall that we get the desired results, with layers of paste being forced into the pores of the surface and adhering to the wall.

The same physical principles are true with shotcrete as with the baseball example. The aggregates and other particles are being blasted out of a nozzle at a high velocity. They are covered with mortar. If the nozzleman keeps the nozzle perpendicular to the surface and makes small circular motions with it, the aggregate particles bounce off the surface and the paste begins to accumulate, creating a sticky surface for subsequent shotcrete material to become compacted into the surface.

For this reason, some rebound is needed and expected. Without some rebound, the desired adhesive properties of the shotcrete will not be achieved. Mortar will either not stick and slough off the surface and fall to the ground, or worse still, fail later on due to poor bonding qualities. This principle holds true for both wet-mix and dry-mix shotcretes. Rebound is, however, inherently higher in the dry-mix shotcrete process than the wet-mix process. More rebound is expected when shooting through welded wire mesh or reinforcing steel. This is especially true if the wire mesh or reinforcing bar is not anchored properly to the surface. The reinforcing material may vibrate when struck by the shotcrete, thus increasing the amount of rebound. Rebound is also higher when there are small openings in the welded wire mesh.



## Conclusions

- Do not reduce the pressure and the velocity of the shotcrete in an attempt to control rebound. Shotcrete is properly applied at high velocity.
- Stay perpendicular to the spraying surface, and not too far away.
- Use small, circular motions instead of large, sweeping circular motions when applying shotcrete to reduce wasteful rebound.
- Start at the bottom and move higher on the spraying surface.
- Rebound from shotcreting onto rock and other hard surfaces will have a dramatic impact on the ratio of rebound to shotcrete adhering to the surface. The amount of rebound will be higher with thin layers of shotcrete.

There is a fine line between too little rebound and too much rebound. If there is too little rebound, there may not be sufficient mortar penetrating the pores on the surface and the bond between the shotcrete and the host surface may be inadequate. Too much rebound results in excessive costs for materials. It is the role of the shotcrete industry to

make known the mechanics of shotcrete application. Shotcrete must be applied properly or it will not deliver the desired performance. We must work to educate owners, architects, engineers, and contractors on the need to use trained and certified personnel to achieve maximum value from the shotcrete process.

## References

1. *Shotcrete Nozzleman Craftsman Workbook*, CP-60, American Concrete Institute, Farmington Hills, MI, 24 pp.



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## *A Compilation of Papers*

This 424-page hardcover book, *Shotcrete: A Compilation of Papers*, is a collection of the most important papers concerning shotcrete by Dudley R. "Rusty" Morgan, PhD, PEng, FACI, FCAE.

Topics in the book include: Shotcrete Research and Development, Freeze-Thaw Durability of Shotcrete, Fiber-Reinforced Shotcrete, Shotcrete for Ground and Underground Support, Infrastructure Rehabilitation with Shotcrete, and Supplementary Shotcrete Publications.

Rusty Morgan has over 40 years of experience in materials engineering, specializing in concrete technology, and is recognized as an authority in shotcrete technology throughout the world. The listing of selected examples of projects he has worked on during his career is over 8 pages long, and his bibliography includes more than 140 peer-reviewed papers. He has also served as editor of several books.



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