# Dynamic Forces during Shotcreting Operations

*by Frédéric Gagnon and Marc Jolin*

Since spring 2001, ACI Shotcrete Nozzleman certification sessions have been held throughout North America. A major portion of the performance examination consists of placing shotcrete in a vertical or overhead panel containing reinforcement. Depending on the location, different setups are used to support these panels firmly and securely, particularly for overhead panels. ACI Committee C660, Shotcrete Nozzleman Certification, has tried to support certification session organizers in designing their panel support setup but, unfortunately, no information is available on the forces exerted on the panel by the shotcrete during placement. Therefore, a simple project was put together to evaluate the shotcrete forces exerted on a panel during the spraying operation in both the wet- and dry-mix shotcrete using full-scale equipment. This project was conducted during the winter of 2007 at the Department of Civil Engineering in Laval University, Québec City, Canada.

## Equipment

Shotcreting activities took place in Laval University's shotcrete laboratory using full-size equipment in a controlled environment. The production and placement of wet- and dry-mix shotcrete was conducted using standard industrial equipment. For dry-mix shotcrete, prebagged dry materials were transported using a rotary barrel-type gun. The dry-mix gun used was a rotating barrel ALIVA 246 with a 1.5 in. (38 mm) interior diameter hose with the water ring placed 5 ft (1.5 m) before the exit of the nozzle (Fig. 1) along with an air compressor having a maximum capacity of 375 CFM at 100 psi (70 kPa) pressure. For wet-mix shotcrete, the premixed shotcrete material was pumped using an Allentown PowerCreter 10 pump combined with a 2 in. (50 mm) interior diameter hose and shot using a 2 in. (50 mm) ACME nozzle (Fig. 2). The laboratory equipment included an electronic air flowmeter (Fig. 3) and an electronic load-measuring system (vertical panel) (Fig. 4) linked to a data acquisition system.

## Regular Shotcreting Operation

Table 1 presents all results obtained for regular shotcreting operations. Maximum horizontal loads on the panel (immediately behind the nozzle

*Table 1: Regular Flow Results—Both Processes*

| Process | At the nozzle | Distance of the nozzle to panel, in. (mm) | Average air flow, CFM | Maximum load, lb (N) |
|---|---|---|---|---|
| Dry-Mix | Air | 12 (300) | 300 | 5 (22) |
| | Air | 36 (900) | 305 | 6 (27) |
| | Air + Water | 36 (900) | 305 | 8 (36) |
| | Air + Water + Material | 12 (300) | 300 | 12 (52) |
| | Air + Water + Material | 36 (900) | 220 | 15 (67) |
| | Air + Water + Material | 36 (900) | 260 | 21 (94) |
| | Air + Water + Material | 36 (900) | 300 | 18 (81) |
| Wet-Mix | Air | 36 (900) | 195 | 6 (27) |
| | Air + Material | 12 (300) | 165 | 46 (205) |
| | Air + Material | 12 (300) | 165 | 39 (175) |

*Fig. 1 : Dry-mix shooting gun and nozzle*

*Fig. 2 : Wet-mix pump and nozzle*

position), average air flow, and approximate distance between the nozzle and the panel are indicated for each trial. The trials were conducted using air alone, air and water, and finally regular shotcrete.

## Plugs Simulation

Supplemental trials were conducted by simulating plugs in the hose with the dry-mix shotcrete equipment. For these trials, water was allowed to fill the hose at the water ring location for about 10 seconds before the air was turned on rapidly using a single ball valve on the main air hose. Considering the safety concerns of such a procedure, only a few trials were attempted. Based on experience, the results are believed to be representative of extreme impact cases. Table 2 presents these results obtained for this somewhat particular condition.

## Conclusion

The force exerted on a panel during the spraying operation in both the wet- and dry-mix shotcrete

*Table 2: Water Plugs Simulation Results—Dry-Mix Process*

| At the nozzle | Distance of the nozzle, in. (mm) | Average air flow, CFM | Maximum load, lb (N) |
|---|---|---|---|
| Air + Water | 36 (900) | 140 | 41 (184) |
| Air + Water | 12 (300) | 285 | 43 (191) |
| Air + Water | 12 (300) | >350* | 63 (279) |
| Air + Water | 12 (300) | >350* | 87 (389) |
| Air + Water | 12 (300) | >350* | 80 (356) |

*Exact value unknown because it was above the maximum capacity of the electronic air flowmeter.


*Fig. 3 : Electronic air flowmeter*

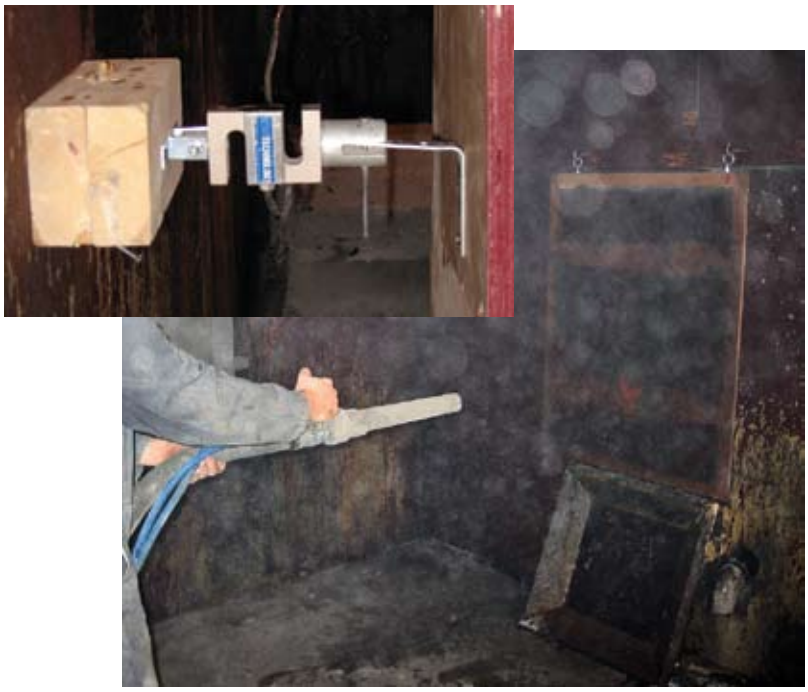

*Fig. 4 : Electronic load measurement system*

processes were successfully evaluated. In normal spraying conditions, wet- and dry-mix shotcretes produced a force on the panel of about 45 and 20 lb (200 and 90 N), respectively. The maximum load recorded is 87 lb (389 N) and it was observed in simulating a water plug.

The authors want to particularly stress that the results presented are not suitable for all shotcreting setups. This experimentation was conducted to provide a general overview of the force applied by shotcrete on a panel with a typical equipment setup for wet- and dry-mix shotcretes. The aim of the study was to provide guidance to designers of panel support systems for ACI Shotcrete Nozzleman Certification. Greater shotcrete dynamic forces could be expected for robotically applied shotcrete using larger-diameter hoses and higher air-flow volumes (CFM).

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