Technology Brief

Slosh Characteristics of Aggregated Intermediate Bulk Containers on Single-Unit Trucks

BACKGROUND

The motion of the liquid in a container, known as slosh, can cause the vehicle carrying the liquid to move appreciably beyond its normal stopping point or normal turning path. Sloshing is most pronounced when a cargo tank is partly full. The dynamics of the interaction of the liquid load and the vehicle must be appreciated by drivers if they are to handle a liquid load safely. This research project was conducted to ascertain whether the slosh characteristics of intermediate bulk containers (IBCs) aggregated to 1,000 gallons or more are similar to a single cargo tank of the same capacity. Key findings are shown in Table 1.

Table 1. Key study findings.

Research Question	Findings
Are slosh characteristics in IBCs aggregated to 1,000 gallons or more similar to a single cargo tank of the same capacity?	No. Study findings indicate that slosh forces in aggregated IBCs are less than slosh forces in a single cargo tank of the same capacity.

IBCs are used to transport small and moderate quantities (119–884 gallons) of liquid. They are often smaller than cargo tanks, and larger than 55-gallon drums or buckets (see Figure 1). IBCs are defined in the hazardous materials code, but they are often used to haul liquids that are not regulated as hazardous. IBCs are commonly shipped by flatbed, van truck, and intermodal container.

A 53-foot trailer will typically reach its allowable gross weight with 18–20 IBCs, depending on the density of the product. That is not enough to fill the floor of the trailer, so proper securement is important to prevent the IBCs from shifting. IBCs are often double stacked, especially in a 20-foot intermodal container, which can usually be filled with IBCs.

STUDY APPROACH

This study consisted of computer simulations and driving experiments on a test track. In both the experiments and the simulations, IBCs half-filled with water were mounted in a two-axle, single-unit truck. Identical simulations were run twice—once with the water free to slosh and once with a rigid load with size and weight identical to the water. Experiments were run only with liquid loads.

Figure 1. Two 550-gallon IBCs mounted at the rear of a truck. The strap that holds them in place is not shown.

Trucks on the test track were driven by experienced tank drivers, who qualitatively compared the effect of sloshing from the IBCs on the truck's behavior on the test track to the effect of sloshing from a cargo tank on the truck's behavior in a real-world driving environment.

The research team developed computer models of liquid cargoes that were half-filled IBCs of two sizes. The IBCs had a nominally rectangular footprint. Simplified models of slosh were used so that they could be combined with the dynamic model of a truck. The simplified models were verified by comparison with more sophisticated computational fluid dynamics (CFD) models. The simulated vehicle executed maneuvers of stopping, turning, and obstacle avoidance to explore the dynamic interaction between the aggregated IBCs and the vehicle.

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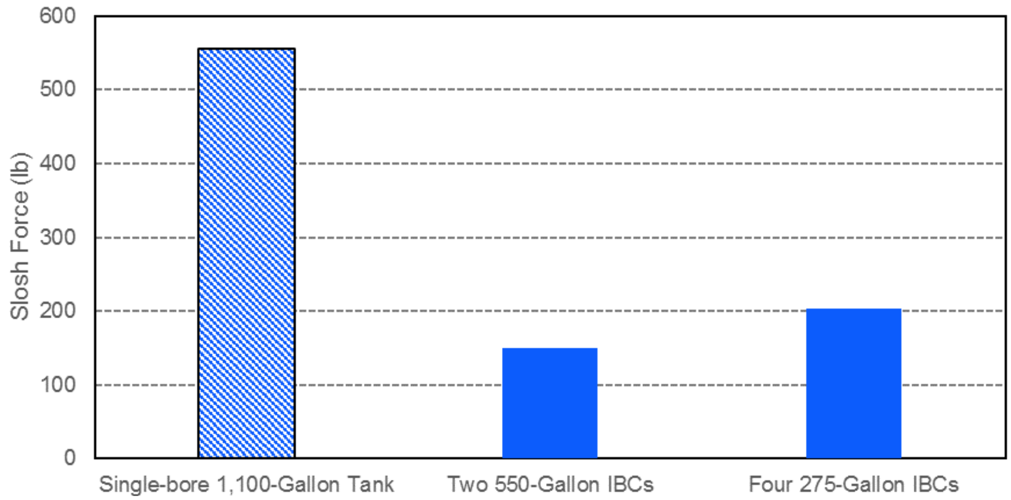

Figure 2. Graph. Lateral force exerted by liquid slosh on a vehicle during a typical lane change. A single 1,100-gallon cargo tank is shown for reference (in "hatched" blue). Two sets of IBCs, both of 1,100 gallon aggregate capacity, are shown in solid blue. The effect of slosh in IBCs of aggregate capacity of 1,100 gallons was less than the effect of slosh in a single 1,100-gallon tank.

FINDINGS

Figure 2 shows the amount of force caused by liquid slosh on a vehicle during a typical lane change. The "hatched" bar represents a half-full, single-bore 1,100-gallon cargo tank. It is included as a basis for comparison. The second bar represents a pair of standard 550-gallon IBCs placed side by side on a truck bed. The third bar represents a set of four standard 275-gallon IBCs placed at the corners of a truck bed. The effect of slosh in the IBCs is smaller than that from the single-bore cargo tank. Though this graph represents only one of the many cases that were simulated, the outcome is representative.

In the most severe cases (e.g., braking to a stop from 55 mi/h in 140 feet or performing a 12-foot lane change at 55 mi/h with a lateral acceleration of 0.5 gravitational units), the force due to slosh in combinations of 275- and 550-gallon IBCs amounted to at most 5 percent of the total loaded weight of the vehicle.

The simulations were supplemented by experiments where two professional tank truck drivers drove two-axle, single-unit trucks on a test track. Both drivers had a tank vehicle (N) endorsement and more than 20 years of tank driving experience. Both drivers felt the effects of the slosh in limited circumstances (see Table 2), and reported that extra skill beyond driving a comparable weight of dry goods was occasionally required to handle the slosh.

The effect of slosh in IBCs in the experiments and simulations was strong in cases where the maneuvers were severe, and the IBCs were purposely positioned to maximize their effect. The effect of slosh in a set of two, three, or four IBCs of common sizes was always less in the simulations than the effect of an equal amount of water in a single cylindrical cargo tank.

To read the complete report, visit: http://ntl.bts.gov/lib/59000/59600/59617/16-006-Slosh-Characteristics-of-Aggregated-IBCs-FINAL-508C.pdf.

Table 2. Driver reports on slosh experienced in each maneuver, using a scale of 1–10 (where higher numbers indicate an increased feeling of slosh).

Maneuver	275-gallon IBCs	550-gallon IBCs
Stop at a red light	One driver felt "very little" slosh immediately after applying the brakes (in one stop).	One driver felt slosh (rated 8/10 in three different stops) of 35 mph .
Deceleration in traffic	One driver felt slosh (rated 7/10 in the lane change that followed deceleration).	One driver felt slosh (rated 7/10 in the lane change that followed deceleration).
Curve on freeway exit ramp	Neither driver felt slosh.	Both drivers felt slosh (rated 7/10). One driver thought the slosh was caused more by a bump in the road than the curve itself, which he rated as 3/10.
Lane change 12 ft over a distance of 171 ft	One driver felt slosh (rated 3/10 at 20–40 mi/h, and rated 9/10 at 45 mi/h).	One driver felt slosh at 45–55 mi/h (rated 5/10). The other driver felt slosh at 45 mi/h (rated 7/10).
Lane change 3 ft over a distance of 86 ft	Neither driver felt slosh.	Neither driver felt slosh.