how many shovels of sand equal 1 cu ft. Since the moisture content of the sand will vary constantly because of temperature, humidity, and evaporation, it is good practice to check the volume measurement at least twice a day and make adjustments as necessary. For even greater consistency, a site-constructed or proprietary batching box can be set to discharge as much as 9 cu ft of sand directly into the mixer (*see Fig. 15-1B*).

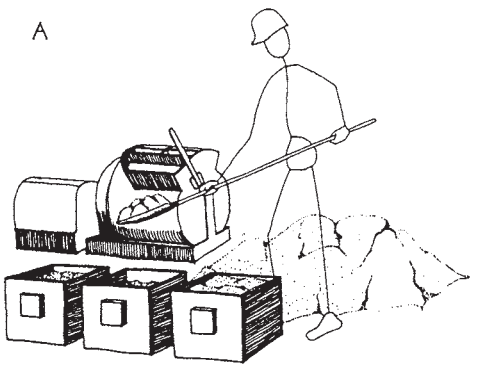
The other dry ingredients in masonry mortar are normally packaged and labeled only by weight. Regardless of weight, however, these cementitious materials are usually charged into the mixer in whole or half bag measures. Each bag of portland cement or masonry cement equals 1 cu ft regardless of its labeled weight, and each bag of hydrated mason's lime equals $1^{1}/_{4}$ cu ft regardless of its weight. In some regions, additional convenience is provided by preblended and bagged portland cement–lime mixes.

Increases in moisture content cause a "bulking effect" in sand. Any given weight of wet sand occupies more volume than the same weight of dry sand, so sand volume may vary throughout the day and from day to day as its moisture content changes.

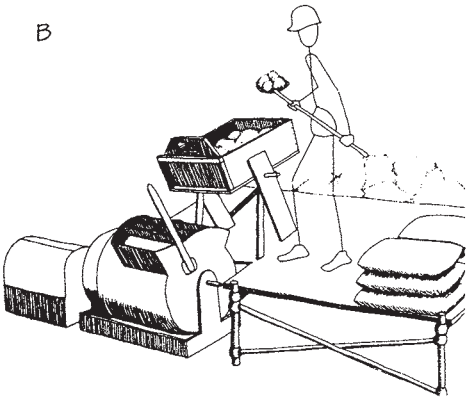
MEASURING SAND SIMPLY BY COUNTING SHOVELS IS NOT AN ACCURATE METHOD OF BATCHING MASONRY MORTAR AND IS NOT RECOMMENDED.

The illustrations below show two alternative methods for accurately measuring sand volume.

- Figure A shows measuring boxes being used to check the number of shovels of sand it takes for 1 cubic foot. Measuring boxes should be used at least twice a day to check sand volume, once in the morning and again after lunch.
- Figure B shows a batching box in which the sand is shoveled into a 1 cubic foot measure and then discharged into the mixer from the box. This method is more accurate and accounts for continuous volume changes in the sand as it dries or bulks with moisture changes.



measuring boxes for checking sand volume during the work day



batching box for accurately and continuously measuring sand volume

Figure 15-1 Measuring and batching sand for masonry mortar. (*From BIA* Technical Note 8B.)

The amount of mixing water required is not stated as part of the project specifications. Unlike concrete, however, masonry mortar and grout require the *maximum* amount of water consistent with characteristics of good flow and workability. Excess water is rapidly absorbed by the masonry units, reducing the water-cement ratio to normal levels and providing a moist environment for curing. Optimum water content is best determined by the mason's feel of the mortar on the trowel. A mortar with good workability is mixed with the proper amount of water.

Mortar with good workability should spread easily, cling to vertical unit surfaces, extrude easily from joints without dropping or smearing, and permit easy positioning of the unit to line, level, and plumb. Dry mixes do not spread easily, produce poor bond, and may suffer incomplete cement hydration. Mixes that are too wet are difficult to trowel and allow units to settle after placement. So mixing water additions are self-regulating. The water proportion will vary for different conditions of temperature, humidity, unit moisture content, unit weight, and so on.

The necessary water content for grout is significantly higher than that for mortar, because grout must flow readily into the cores and cavities and around reinforcement and accessories. Grout consistency should be such that at the time of placement, the grout has a slump of 8 to 11 in. (*see Fig. 15-2*).

Recent innovations in masonry technology include ready-mixed mortars and prebatching of dry mortar ingredients to eliminate the field variables that often affect the quality and consistency of job-mixed mortar. This moves the mixing operation to a controlled batching plant where ingredients can be accurately weighed and mixed, then delivered to the job site. Ready-mixed mortars are delivered trowel-ready in trucks or sealed containers, without the need for additional materials or mixing. Extended-life set retarders, which keep the mix plastic and workable for up to 72 hours, must be absorbed by the masonry units before cement hydration can begin, so unit suction can affect set time and construction speed. Prebatched dry ingredients are delivered to the site in weathertight silos ready for automatic mixing (*see Fig. 15-3*). Both methods improve uniformity and offer greater convenience and efficiency, but sand bulking can still be a problem with dry-batched mixes unless the sand is oven-dried. Ready-mixed mortars are governed by ASTM C1142, *Standard Specification for Ready-Mixed Mortar for Unit Masonry*.

There are two traditional methods of mixing mortar on the job site. For very small installations, *hand mixing* may be most economical. It is accomplished using a mason's hoe and a mortar box. Sand, cement, and lime are spread in the box in proper proportions and mixed together until an even color is obtained. Water is then added, and mixing continues until the consistency and workability are judged to be satisfactory.

More commonly, *machine mixing* is used to combine mortar ingredients. The mechanical drum or paddle-blade mixers used are similar to but of lighter duty than concrete mixers. Normal capacity ranges from 4 to 7 cu ft. About three-fourths of the mixing water, half the sand, and all of the cementitious ingredients are first added and briefly mixed together. The balance of the sand is then added, together with the remaining water. After all the materials and water have been combined, grout should be mixed a minimum of 5 minutes, and mortar a minimum of 3 and a maximum of 5 minutes. Less mixing time may result in non-uniformity, poor workability, low water retention, and less than optimum air content. Overmixing causes segregation of materials and entrapment of excessive air, which may reduce bond strength.