CIP 8—Discrepancies in Yield

WHAT is Concrete Yield

Concrete yield is defined as the volume of freshly mixed concrete produced from a known quantity of concrete materials. Ready mixed concrete is sold on the basis of the volume of fresh, unhardened concrete in cubic yards (yd^3) or cubic meters (m^3) as discharged from a truck mixer. Most materials are batched by weight so it is important to determine the volume of concrete produced from the actual batched quantities of materials. The density of the fresh concrete is used to establish this relationship.

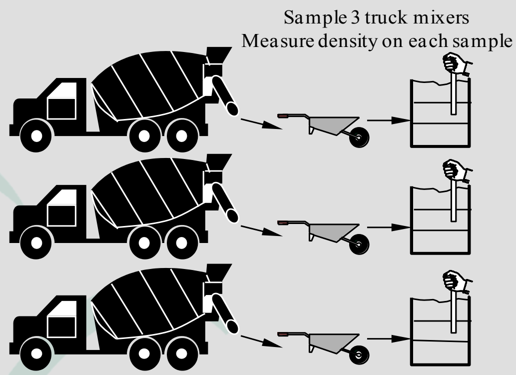
The basis for calculating the volume or yield is described in ASTM C94, *Specification for Ready Mixed Concrete*. The volume of freshly mixed and unhardened concrete in a given batch is determined by dividing the total weight of the materials by the density (unit weight) of the concrete determined in accordance with ASTM C138. ASTM C94 requires that the yield should be determined from the average of three determinations of representative samples, each from three different delivery vehicles. It should thereby be recognized that the volume of concrete supplied is not determined from the calculated dimensions of the constructed member.

A note in ASTM C94 states: *It should be understood that the volume of hardened concrete may be, or appears to be, less than expected due to waste and spillage, over-excavation, spreading forms, some loss of entrained air, or settlement of wet mixtures, none of which are the responsibility of the producer.*

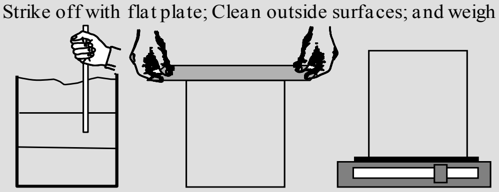
The volume of hardened concrete in place may be about 2 percent less than its volume in a freshly mixed state due to reduction in air content, settlement and bleeding, decrease in volume of the cementitious paste, and drying shrinkage due to loss of moisture.

WHY do Yield Problems Occur

Yield discrepancies can be real or perceived. Real discrepancies result when quantity of materials batched do not produce the intended yield. This can be evaluated by density measurements. If yield determined from density measurement indicates a discrepancy, it should be corrected by the concrete producer. Perceived discrepancies, typically under-yield, is when the concrete ordered does not fill the forms due to contingencies discussed below:



ASTM C138 - Test for Density (Unit Weight)
Fill density measure in 3 layers;
Rod each layer 25 times; tap sides with mallet;
Strike off with flat plate; Clean outside surfaces; and weigh



$$\text{Density, lb/ft}^3\ (\text{kg/m}^3) = \frac{\text{Wt. of concrete in measure, lb (kg)}}{\text{Volume of measure, ft}^3\ (\text{m}^3)}$$

$$\text{Average Density, lb/ft}^3\ (\text{kg/m}^3) = \frac{(\text{D1} + \text{D2} + \text{D3})}{3}$$

$$\text{Batch Yield, yd}^3 = \frac{\text{Weight of Materials in Batch, lb.}}{\text{Average Density, lb/ft}^3 \times 27}$$

$$\text{Batch Yield, m}^3 = \frac{\text{Weight of Batch, kg}}{\text{Average Density, kg/m}^3}$$

a. Miscalculation of form volume or slab thickness when the actual dimensions exceed the assumed dimensions used in estimates, even by a small amount. For example, a 1/8-inch (3-mm) difference in a 4-inch (100-mm) thick slab would mean a shortage of 3 percent or 1 yd^3 in a 32-yd^3 (1 m^3 in a 32-m^3) order.

b. Deflection or distortion of the forms resulting from pressure exerted by the concrete.

c. Placement on irregular subgrade or granular fill and settlement prior to or during placement.

d. Over the course of a large job, the small amounts of concrete returned each day or used in mud sills or incidental footings can add up to be perceived as a deficiency in yield.

An over-yield can be an indication of a problem if the excess concrete is caused by too much air, water, or aggregate, or if the forms have not been properly filled.

Differences between actual and target weights and air content in concrete, within the permitted tolerances, will result in discrepancies in yield.

HOW to Prevent Yield Discrepancies

To prevent or minimize concrete yield problems:

a. Check concrete yield by measuring concrete density in accordance with ASTM C138 early in the job. Repeat these tests if a problem arises. Ensure that the scale is accurate and placed on a level surface, that the volume density measure is accurately determined, that a flat plate is used for strike off, and that the outside of the measure is cleaned prior to weighing. Concrete yield in ft^3 (m^3) is total batch weight in pounds (kg) divided by density in lb/ft^3 (kg/m^3). The total batch weight is the sum of the weights of all materials from the batch ticket.

b. Measure formwork accurately. Order sufficient quantity of concrete to complete the job and reevaluate the amount required towards the end of the placement. Provide this estimate to the concrete producer so that the order for the last 2 or 3 loads can be adjusted to provide the required quantity of concrete. This can prevent waiting for a short load after the plant has closed or the concrete trucks have been scheduled for other jobs. Disposal of returned concrete has environmental and economic consequences to the concrete producer and the purchaser.

c. Estimate extra concrete needed for waste and increased placement dimensions over nominal dimensions. Include an allowance of 4 to 10 percent over plan dimensions for waste, over-excavation and other contingencies. Repetitive operations and slip form placement permit more accurate estimates of the amount of concrete that will be needed. Sporadic operations involving a alternating placement in slabs, footings, walls, and as incidental fill around pipes will require a bigger allowance for contingencies.

d. Construct forms with adequate bracing and shoring to minimize deflection and bulging when concrete is placed. This is important for elevated slabs.

e. For slabs on grade accurately finish and compact the subgrade to the proper elevation.

Example—Materials batched for 8 yd^3 / 6 m^3 load.

Material	Weight, lb	Weight, kg
Cement	3,620	1,640
Fly ash	920	420
Coarse Aggregate	14,400	6,550
Fine Aggregate	11,200	5,090
Batch Water	2,080	940
Total	32,220	14,640
Density, lb/ft^3 / kg/m^3	151.0	2,430

$$\text{Yield} = \frac{32{,}220}{151.0 \times 27} = 7.9\ \text{yd}^3$$

$$\text{Yield} = \frac{14{,}640}{2{,}430} = 6.0\ \text{m}^3$$

References

1. ASTM C94 and C138, ASTM Book of Standards, Volume 04.02, ASTM International, West Conshohocken, PA. www.astm.org
2. *Ready Mixed Concrete,* Gaynor, R.D. & Lobo, C.L., NRMCA Publication 186, NRMCA, Silver Spring, MD, www.nrmca.org.
3. *Users Guide to ASTM C94,* Daniel, D.G. & Lobo, C.L., NRMCA Publication 2PMNL49, 2nd edition, NRMCA, Silver Spring, MD, www.nrmca.org.
4. *Improving Concrete Quality*, Obla, K.H., CRC Press, available from NRMCA, Silver Spring, MD.
5. *No Minus Tolerance on Yield*, Malisch, W. R. and Suprenant, B. A., Concrete Producer, May 1998.
6. *Causes for Variation in Concrete Yield*, Suprenant, B. A., The Concrete Journal, March 1994.

Follow These Rules to Avoid Yield Discrepancies

1. Measure forms and accurately estimate the volume of concrete needed.
2. Estimate potential waste, additional thickness, form deflection and other contingencies—order more than the original volume estimate by at least 4 to 10 percent
3. Towards the end of the placement reevaluate required volume and inform the concrete producer with adequate time to adjust subsequent loads. Avoid short loads to complete a placement.
4. To check yield, measure the density of representative samples from three separate loads—yield is the total batch weight for each load divided by the average density.

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