PROCEDURE

A. Measuring the natural angle of repose for a coarse aggregate

Research references to learn what the natural angle of repose for an earth material represents: How does this relate to the internal angle of friction of the material?

What does this mean about the characteristics of the material?

Using the image in Figure 1 below, consider the dashed line labeled "Base diameter" as representing a horizontal line. Using a straight edge or ruler, draw a line that follows the edge of the stockpile from the base diameter line to the top of the stockpile. With a protractor, measure the angle between the line that you just drew and the dashed line. This angle is the natural angle of repose for this particular natural gravel, a coarse aggregate material.

Angle of repose = _____degrees

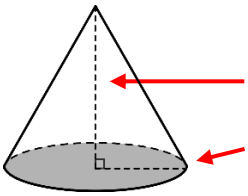
Examine information available about the natural angle of repose of various materials online or from reference sources and see how your measurement compares with values in the literature for sand, crushed stone, natural gravel, soil, shelled corn, soybeans, etc.

How could this knowledge help you plan for storage of these materials in open or covered piles?

What would you build or do to limit the size of the base of a pile of one of these materials?

B. Computing the volume of coarse aggregate in a conical shaped stockpile

Consider the formula for calculating the volume of a cone (text box below). Then measure the diameter of the base of the conical end of the stockpile shown in Fig. 1 using the scale bar to determine the diameter of the stockpile base. Calculate the radius of the base (R=1/2 Diameter--assume that it is a single conical shaped pile standing by itself). In the same manner, determine the height of the stockpile. Place these measurements in the formula for the volume of a cone and complete the arithmetic to find the volume.



Cone

Height (h)

Base radius (R)

Formula to calculate the volume of a cone:

$V = 1/3\ \pi\ R^2\ h$

Where:

V = Volume π = pi (3.14159)

R^2 = Radius x Radius h = Height

Height = _____feet Diameter = _____feet x ½ = Radius in _____feet

1/3 x 3.14159 x Radius_____ ^{2} x height_____ = Volume_____ cubic feet

C. Calculating the volume of coarse aggregate stockpile to the volume of Portland Cement (PC) concrete used per length of highway pavement

Portland Cement concrete (PC concrete) is used for myriad construction purposes. PC concrete is made from carefully sized and clean (no fine particles such as silt or clay) coarse aggregates such as natural gravel or crushed stone, natural or manufactured sand (again with no silt or clay), Portland cement, and water. Often substances are added to this mixture to strengthen the final product, control the wet, mixed materials' flow characteristics, or to control the rate at which the reactions occur that make the PC concrete cure (harden) to its intended strength. The proportions of these additional ingredients to the PC concrete mix are adjusted to provide the desired properties, such as strength, in the final, fully cured product.

For the following calculations, assume that the Portland Cement, fine aggregate (sand), and coarse aggregate (gravel) are mixed in these proportions: one part Portland Cement to two parts sand to three

parts gravel, *i.e.,* ! : 2 : 3 ratio. This is the basic mix recipe that has been used historically for many applications of PC concrete in construction. However, many other mix ratios are used for particular applications of PC concrete. A variety of additives may be used in the mix to give the freshly mixed concrete beneficial characteristics for placement, curing, etc., as well as finished properties such as strength, waterproofness and wear resistance. The amount of water added to this mix of dry substances not only influences the handling and workability of the wet mix but it also influences the ultimate strength of the placed and cured (hardened) PC concrete.

Calculations:

Use the mix ratio of 1 : 2 : 3 (1 Portland Cement, 2 parts sand, to 3 parts gravel) for this calculation. With a limiting factor of the volume of 10 stockpiles of gravel like the one shown in Fig. 1 for which you have calculated the volume of gravel in the stockpile, calculate how many cubic feet of PC concrete can be mixed using that volume of 10 piles of gravel. (Assume the needed amounts of Portland Cement, sand, and water are available.)

Volume of PC Concrete and Length of Pavement:

Total (10 piles) volume of gravel available: above Volume _____ x 10 = _____ cubic feet

At a mix ration of 1 part cement, 2 parts sand, and 3 parts gravel, gravel constitutes 3/6 of a batch or half of the batch. (1 volume of cement + 2 volumes of sand + 3 volumes of gravel = 6 volumes of dry concrete mix or batch.) Hence, the gravel volume multiplied by two (2) gives the mixed concrete volume.

Thus: _____ cubic feet of available gravel x 2 = _____ PC Concrete volume
* This assumes no loss of volume upon mixing.

Assuming that 1 foot of a single lane of PC concrete pavement is 1 foot thick and 12 feet wide, what length of a single lane of pavement can be constructed using the volume of PC concrete mix from calculation 1, above, from the 10 equally sized conical stockpiles of gravel as the coarse aggregate?

0ne lineal foot of this pavement is 1 foot thick by 10 feet wide and 1 foot long. Hence, each lineal foot of pavement has a volume of 1 foot x 1 foot x 10 feet = 10 cubic feet.

The length of pavement that may be constructed from the 10 conical stockpiles of gravel is

_____ cubic feet of PC concrete mix/10 cubic feet per linear foot = _____feet of pavement.

How many miles does this equal? _____