

promised the matter with the Government by offering to reimburse a certain sum on the overpaid dredging. From the very contradictory evidence given in the case, varying from nought to 40 per cent., it would appear that this expansion of excavated or broken and disintegrated material is a very much unknown quantity, and in fact very little that is reliable is known on the subject. In reality, such expansion varies from $\frac{1}{4}$, or 87½ per cent., in the case of a solid cubic yard of stone broken into road metal, not only down to nothing, but in certain cases or with certain soils passes to the other side of zero, and becomes minus or a shrinkage or diminution of the material excavated or loosened into its elementary parts.

Very few authors allude to the subject in any way, and few or no experiments have been made to ascertain and tabulate the ratios and their time-varying values.

Trautiome has it, under the heading not of expansion, but of "Shrinkage of Embankment;" that "Although earth when first dug and loosely thrown out, swells about one-fifth part, so that a cubic yard in place averages about one and one-fifth, or 1.2 cubic yards when dug; or one cubic yard dug is equal to five-sixths, or to .8333 of a cubic yard in place, yet, when made into embankment, it gradually subsides, settles or shrinks into a less bulk than it occupied *before being dug.*"

He gives the following approximate averages of the shrinkage; or, in other words, the earth measured in place in a cut, will, when made into embankment, occupy a bulk less than before by about the following proportions:

Gravel or sand about 8 per cent.,	or 1 in 12½ less
Clay or sand about 10 "	or 1 in 10 less
Loam " 12 "	or 1 in 8½ less
Loose vegetable surface soil,	15 " or 1 in 6¾ less
Puddled clay	25 " or 1 in 4 less.

He adds that from some trials of his own, 1 cubic yard of any hard rock in place will make from 1¾ to 1½ cubic yards of embankment, say an average of 1.7 cubic yards; or that one cubic yard of rock embankment requires .5882 of a cubic yard in place. He found that a solid cubic yard, when broken into fragments, made about (1) 1.9 cubic yards of loose heap; (2) 1½ yards carelessly piled, (3) and 1.6 yards carefully piled; or (4) 1½ cubic yard of very carelessly scabbled rubble; or (5) 1¼ yards of somewhat carefully scabbled; or, in other words, that

No 1 gives of solid parts	.526,	and of voids	424=1000
No 2 "	"	570 "	" 430=1000
No 3 "	"	630 "	" .370=1000
No. 4 "	"	.670 "	" .330=1000
No 5 "	"	800 "	" .200=1000

It need hardly be said that in dealing with such comparatively non-absorbing material as solid stone, these ratios can easily be obtained by weight or by the quantity of water displaced.

These figures of Trautiome I am in a position to substantiate only as regards a solid yard of stone reduced to road metal, the solid yard weighing two tons, or 4,480 pounds; while the same bulk of metal gives only 2,440 pounds, or little over one ton, as ascertained by actually weighing a cubic yard of the metal as a basis from which to determine the number of cubic yards supplied and to be paid for on our Quebec contracts, of about 30,000 cubic yards, for the last two years.

Now, while common earth or dirt, when freshly

excavated, may swell some 20 per cent., or one fifth, as Trautiome says, such is not the case with sand of the description dredged on the site of the Quebec Harbor works; nor has the writer upon trial found it to expand or occupy in the loose a bulk greater by more than 5 per cent. than in the solid or *in situ*, and from experiments purposely made from successive heights by the writer, and on which to base his testimony as given in the Exchequer Court in suit alluded to, he found that the wet sand, as excavated and handed up by the dipper and then dumped into the scow, did fall just with such a thud or force or weight of impact as to consolidate it or cause it to enter into exactly the same space as it occupied *in situ* in the bed of the river, and that consequently the contractors could claim no allowance for expansion on material of the kind.

Many apparently plausible arguments were adduced to shake the faith of the court in the premises; that is, in the result arrived at by the experimental work of Mr. Steckel on some 1,500 yards of the material, as already stated, such as the fact of the out or overflowing water from the surface carrying with it a heavy percentage of the stuff; and so it would, had it been mud or sludge instead of sand; as if the court were blind enough not to see that even if the assertion were true it would be no argument against the correctness of the result arrived at, since the stuff, if any, falling overboard, would flow or fall back into the excavation being made, and be scooped or dipped up again, and again find its way into the scow.

Col. Moore, who as a contractor on many dredging operations, had never heard of any expansion or swelling of excavated material beyond 14 to 20 per cent., instead of 33, showed how in some cases the scow measurement actually ran short of the quantities *in situ* by the fact that in tidal waters, or with a greater or less strength or velocity of current keeping the loosened material in suspension, much of it was actually floated away, the current in such case doing a notable percentage of the work for which the contractor was being paid.

It was argued also in the case that the quantities were increased by the material introduced from some 100 acres of the city drainage; but it could not be shown that this would have given more than the fraction of an inch over the dredged area, as though some trifling sewer sediment might, under the velocity due to its coming from the city heights, reach the docks, the almost immediate reduction of this velocity to nought on reaching tidal level, would cause such sediment or material to settle down immediately, and short, by hundreds of feet, of the site of dredging operations.

Of course there is an expansion or an allowance which should be made over and above net quantities in estimating dredging and excavation of every kind; but this hinges in no way on swelling of the material to be taken out, but on the fact that such dredging or excavation can not be confined to the exact figure of the section, and there is of course a tendency in our human nature to overdo the thing a little or travel into side issues, when paid for by the yard at a good round paying price; as in tunnelling for the New York aqueduct, where the price per cubic yard of rock excavation was some \$7, if the writer remembers well, holes were found in which a man could stand erect above the brick vaulting or lining of the tunnel, or between the extrados thereof and the top or roof of the excavated space.

That material thrown into embankment should give