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A practical guide to mortar mix ratios and making repeatable and consistent mortars

Have you ever wondered where 1:3, 1:2:9 or 1:1:6 mixes come from?
Even builders who have been building all their working life often don't know where these familiar and well used mix proportions come from!

Explanation of mortar mix ratio notation
The first digit, or first two digits of a mix proportion refer to the binder content (i.e. lime or cement or both) and the last digit always refers to the filler, which is usually sand. So a 1:3 mix could mean 1 part by volume of cement to 3 parts by volume of sand, or it could mean 1 part by volume of lime to 3 parts by volume of sand. A 1: 2:9 could mean 1 part by volume of cement (the gauging material) to 2 parts by volume lime to 9 parts by volume of sand, and so on.

In all these mixes, the end game is to coat all the sand grains with binder to make a complete mortar.
Get your head around this!, a 1:3 mix when prepared as a mortar will still have the same volume as the 3 volumes of sand you started with (the only science where 1 and 3 parts mixed together doesn't make 4!). This is because there are voids or spaces between the sand grains which when combined with just the right amount of binder will fill all these voids or spaces. The mix ratios quoted above are based on using sands which have void ratios or spaces equating to around 1/3 of their volume, hence the 1 part by volume of binder to 3 parts by volume of sand, where 1/3 of the sand volume is filled by binder (i.e. 1/3 in percentage terms equals 33%). When you get onto 1:2:9 mixes effectively you have 3 parts binder to 9 parts sand which equates to 1 part binder by volume to 3 parts sand by volume, i.e. 1:3.

It's important to know the void ratio of your sand so that you use sufficient binder to make a complete mortar, if you don't then you might have an expensive failure on your hands!
It's easy to measure the void ratio of sand on site, you can do it with a clear jam jar of a known volume (at least 100ml). Mark off 10ml divisions with a permanent marker pen on the side of the jar. Fill the jar with 'bone dry' sand (dry it out on stages in a microwave oven) to the 100ml mark and tamp down lightly, then measure 100ml of water in a different container. Slowly pour the water into the jam jar of sand until the water level is equal with the top of the sand level. Note – you will need to do this in stages to allow water to percolate into the voids or spaces. The volume of water required to reach the top surface of the sand is equivalent to the void ratio in percentage terms. So if you need 25 mls of water to reach the top surface of the sand then the void ratio of your sand is 25%. In some instances, you will find that some sands will have a void ratio exceeding 50% so you will need to up your binder content accordingly.

Top tip! Always use 100ml measures to make working out percentages easier.

When quoting mix proportions, you are stating the mix ratios nominally by volume, but on a practical basis measuring lime and other powder binders by volume is unlikely to be accurate and can lead to the production of inconsistent mortars of differing strengths and performance qualities and sometimes failures. For this reason, when using dry hydrate powders, we need to measure them by weight in order to be accurate and consistent and rule out at least one of the many causes of mortar failure.

Try this out for yourself!

Carefully fill a dry plastic container (say 500ml volume) with a dry hydrate binder (it could be cement or a lime binder) tamping down firmly and tapping the side with a spoon after each fill to remove the air content. Once you have firmly packed the container to the very top, get a colleague to empty out the container into a wide bowl and refill the container without tamping down in say 30 seconds. See just how much binder is left over in the bowl! Translate this experiment onto a building site and you could be very shy on your binder content and very

inconsistent into the bargain. This is why we recommend you weigh out your lime binders on site using a spring balance (like fishermen use) or else a set of bathroom scales.
Top tip! Remember to 'zero' your scales to take account of the weight of your bucket or container used to measure the lime, a standard builders' bucket can weigh up to 1kg empty.

Now lets have a look at all the different binders available, they usually come in 25kg bags (with the exception of St Astier NHL 5 bags which weigh 30kg). If you lined up all the bags of binder on a bench you would see that the bags are of varying sizes (i.e. volumes) but all weigh the same. In particular, you will notice the bag of Ordinary Portland Cement (OPC) is the smallest (i.e. least volume) Why is this? It's to do with the surface area of the particles of cement and therefore the number of particles in a material. For instance, on an area of 1 centimetre square, you could 'stick' 3,600 particles of standard OPC ,1 particle thick. Using a feebly hydraulic lime you could 'stick' 13,000 particles over the same area. In short, cement particles have a greater surface area and are heavier than those of most lime binders. Hence, it takes a lesser number of particles and lesser volume of OPC to reach 25kg than say feebly hydraulic lime which takes more particles (because of the smaller surface area) and therefore more volume to reach 25kg, therefore the bag is bigger. The differences in the volumes of binder for the same weight are known as **relative bulk densities**. Each binder will be different even though they may be in the same British Standard classification (BS-EN 459), e.g. St Astier NHL 2 will have a different relative bulk density than say Otterbein NHL 2 because they are all made from naturally occurring limestones.

Top trick! What's heavier a pound of feathers or a pound of lead? Neither, they both weigh the same!

So now do you see that 1 volume of a binder can be a different weight from 1 volume of another binder? If we know the relative bulk density of a binder we can work out the weight of a given volume.

Many bags of binder will have the relative bulk density printed on them, but many don't. Some bags will give you workings out for full bag mixes which is very helpful if you want to produce larger amounts of mortar.

Top tip! If you are in any doubt, you should ask your mortar supplier for the relative bulk density of your chosen binder, if they don't know, they are not worth their salt, steer clear and find someone who can give you this important information.

Once you have clarified the relative bulk density of your chosen binder(s) you are ready to go!

So how to we convert a mix ratio that is quoted nominally by volume to a weight?
The simplest way of understanding this is to take the relative bulk density figure (rbd), e.g. 0.63, this means that 1 litre of this lime binder weighs 0.63kgs and take it from there…

But there are a number of ways of working this out, probably one of the most useful ways is to work out how much mortar you are going to need for a day's work, this is equivalent to the volume of sand you are going to use (because if you remember the binder only fills the voids or spaces between the sand grains!).

Example – Joe, the Foreman Mason on a pointing job reckons he is going to need 50 litres of mortar to keep each of his 3 masons going for the day, i.e. a total of 150 litres of mortar. Joe knows he will need 150 litres of sand (or 10 no. 15 litre builder's buckets), he knows he wants to make his mortar in a 1:2 ratio (i.e. 75 litres of lime) using a feebly hydraulic lime binder which has a rbd of 0.5, but how much lime by weight will he need? Joe works out he needs the equivalent of 75 litres of his chosen lime (i.e. ½ of 150 litres of sand as it is in the ratio of 1:2), but how much does this weigh? If the rbd of Joe's lime is 0.5 then this means that 1 litre of lime weighs 0.5kg, therefore 75 litres of this lime weighs 75 x 0.5 = 37.5kg of lime.

Put into a formula this calculation reads like this…

Known volume of lime binder required x rbd of the chosen lime = weight equivalent of lime to be used in kgs.

Top tip! Write down your volume to weight calculations in your site diary

Here's another example…

Fred, the Lead Mason has been asked by the site manager to get a move on with his harling work, all the surface preparation work has now been done and Fred is ready to start spray harling. Fred has an area of 50m2 to coat twice, the first coat has to be up to 10mm thick and the second coat up to 8mm thick, both mixes are in the ratio 1:2.5 (or 2:5). Fred is going to use a feebly hydraulic lime binder with an rbd of 0.63 for both coats. For the first coat, Fred will need 50 x 0.01 (i.e. 10mm as a function of 1metre) = 0.5 cubic metres or M3 of material, which is also his sand content, i.e. 500 litres of material/ sand. Fred works out what volume of lime binder he needs based on a 1:2.5 ratio or 2:5 ratio. If 5 parts by volume = 500 litres, then 2 parts by volume equals 200 litres. So Fred needs 200 litres of lime binder. How much does this weigh? Fred gets out his winning formula…

Known volume of lime binder required x rbd of the chosen lime = weight equivalent of lime to be used
200 litres of lime x rbd of 0.63 = 126 kg
Fred now knows he needs 126kg of lime and 500 litres of sand for his first coat.

For the second coat, Fred will need 50 x 0.008 (i.e. 8mm as a function of 1metre) = 0.4 cubic metres or M3 of material, which is also his sand content, i.e. 400 litres of material/ sand. Fred works out what volume of lime binder he needs based on a 1:2.5 ratio or 2:5 ratio. If 5 parts by volume = 400 litres, then 2 parts by volume equals 160 litres. So Fred needs 160 litres of lime binder. How much does this weigh? Fred gets out his winning formula…

Known volume of lime binder required x rbd of the chosen lime = weight equivalent of lime to be used
160 litres of lime x rbd of 0.63 = 100.8 kg
Fred know he needs 100.8kg (rounded up to 101kg) of lime and 400 litres of sand for his second coat.

Top tip! 1 cubic metre or 1M3 is 1000 litres of material

Top tip! Mortar ratios of 1:2.5 are the same as 2:5

Top tip If you calculate your lime binder weight with silly decimal point values, e.g. 168.25 kg then round it up to the nearest sensible whole measure, i.e. 170kg, this is absolutely fine to do as you will not be shy on your lime but you must be consistent in applying this rule!

Another example…
Jim the roofer has been asked to bed some new chimney cans on a tenement building in Glasgow. Jim knows he needs to use an eminently hydraulic lime mortar, which will set up quickly enough to be robust in a very exposed environment. Jim intends to use the Portuguese eminently hydraulic lime called Cimpor in a 1:1.5 ratio with a well graded concrete sand. Jim reckons he needs only 20 litres of mortar to do the job, therefore he needs 20 litres of sand. The volume of lime Jim needs is 20 litres divided by 1.5 = 13.3 litres, or you can work it out in whole numbers like this: 1:1.5 ratio is equivalent to 2:3 (both sides doubled up), we know Jim needs 20 litres of mortar using 20 litres of sand. In this case, 3 parts by volume of sand = 20 litres, so 1 part by volume is 20 litres divided by 3 = 6.66 litres and therefore 2 parts by volume is 6.6 x 2 = 13.3 litres. The rbd of Cimpor is 0.9, i.e. 1 litre of Cimpor weighs 0.9kg. Jim gets out his winning formula…

Known volume of lime binder required x rbd of the chosen lime = weight equivalent of lime to be used
13.3 x 0.9 = 11.99kg of lime, round this up to 12kg and make a note of it in your site diary.

Top tip! Where you have fractions as part of your mix ratio, e.g. 1:2.5 or 1:1.5, double them up to 2:5 and 2:3 respectively, this makes calculating the volume of lime required much easier.

Have fun measuring and mixing knowing you are going to produce repeatable and consistent mixes! It will save you time and money in the end…

Happy mixing!