

A Mixing Model to Predict Selected Parameters in Mixing Container Media

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Abstract

The aim of the study was to get accurate data on the effects of mixing container media components and to match these data against models for mixing container media. It was accepted that the mixing of two container media components was related linearly to the amounts of material mixed, for parameters such as degradability. For other parameters the extra material necessary to compensate for the effect of interstitial filling had to be taken into account. Four different two component mixes were measured for 36 different ratios in all. Moisture content, air content, shrinkage, density and EC and pH were measured for each mixture. A formula based on measured densities of the components and the mix was used to predict moisture/air content in the mixes. It is concluded that the formula and the underlying method underestimate the water content in relatively wet materials such as peat-coir products and overrate the moisture content for relatively dry materials such as peat and flax straw mixes. The increase in density of the mix may be calculated either by measuring the volume loss or the density increase of one or more test mixes, from modelling a simplified particle size distribution, or from an empirically calculated relationship with particle size distribution parameters.

INTRODUCTION

For several decades at least, soil scientists have attempted to estimate the quality parameters of container media mixes from measurements of those quality parameters in the single components of the mix. An obvious first step is the directly proportional calculation in formula 1.

$$X_{1,2} = C_1 X_1 + C_2 X_2 \quad (1)$$

where $X_{1,2}$ is the calculated estimation of quality X in the mix of component 1 and 2; C_1 is the ratio of component 1 in the mix; C_2 is the ratio of component 2 in the mix; X_1 is quality X in unmixed component 1; and X_2 is quality X in unmixed component 2.

This formula is successful for properties which are not dependent on the bulk density of the mix such as the particle distribution. It is not suitable for properties which change with changes in bulk density of the mix such as EC. The formula may incidentally be correct when components to be mixed have similar distributions of non-compressible particles like sandy composts or equally compressible particles like some peats and coir pith.

An important step to make the formula more general was the addition of a factor for the change in volume due to interstitial filling. Interstitial filling is the common change in density when two or more media with a different particle size distribution are mixed and the smaller particles fill space which was not previously occupied. The formula can, dependent on what is more convenient, be based on volume loss or on density increase as shown in, respectively, formulae 2a and 2b.

$$X_{1,2} = (c_1 * X_1 + c_2 * X_2) / (1 - S_{1,2}) \quad (2a)$$

where $X_{1,2}$ is the calculated estimation of quality X in the mix of component 1 and 2; C_1 is the ratio of component 1 in the mix; C_2 is the ratio of component 2 in the mix; X_1 is

quality X of component 1; X2 is quality X of component 2; and S is the volume loss as a fraction of the total volume before mixing (i.e. $c_1 + c_2$).

$$X_{1,2} = (C_1 \cdot X_1 + C_2 \cdot X_2) \cdot (D_{x1,2} / (C_1 \cdot D_{x1} + C_2 \cdot D_{x2})) \quad (2b)$$

where $X_{1,2}$ is the calculated estimation of quality X in the mix of component 1 and 2; C_1 is the ratio of component 1 in the mix; C_2 is the ratio of component 2 in the mix; X_1 is quality X of component 1; X_2 is quality X of component 2; $D_{x1,2}$ is the measured density of the mix; D_{x1} is the density of component 1; and D_{x2} is the density of component 2.

A drawback when applying formula 2a and 2b is that the volume loss or density increase on mixing has to be measured as an extra parameter. This is often acceptable as the measurement is not complicated. The formula is valid for most materials. Results previously reported showed excellent correlations (Nash and Pokorny, 1990, 1992; Pokorny and Henny, 1984).

Another approach is to use particle size analysis to feed a model which calculates the theoretical increase in density due to mixing (Bures et al., 1993). An advantage is that predictions of a mix can be based on measurements of the growing medium constituents only i.e. without additional measurements on the mix. Possible drawbacks of this procedure are that the particles are assumed to be perfectly spherical and perfect packing of the particles is presumed (Bures et al., 1993).

MATERIALS AND METHODS

In a laboratory experiment several series of mixes of two components were produced. The moisture content and air content of the various mixes and their densities were measured with sandboxes for water retention measurements (CEN, 1998). Only the data for laboratory container capacity are discussed in this paper.

As most container media mixes used for container plant growing, are peat-based, milled Baltic white peat was used as the base constituent. For mixing with the milled white peat, fraction number two white peat sods (8-16 mm), coir fiber mix, flax straw and reed straw were used. Coir fiber mix is a mixture of 30% v/v 1-2 cm coir fibers and 70% V/V Irish milled peat. The flax straw is a common waste product after fiber extraction from flax stems. The durability of the reed straw had been increased by mild heating in an oxygen free atmosphere i.e. torrefied.

The Baltic white peat was mixed with fraction two peat in a series ranging from 0 to 100% fraction two particles in incremental steps of 10%. The other series were prepared by mixing Baltic white peat with 0-50% coir fiber mix, flax straw and reed straw in incremental steps of 10%. The fibrous materials were not added in levels exceeding 50% as fibrous materials like coir fiber mix, reed and flax straw are used in practice to increase the air content in container media by adding quantities of 10-30% only.

The particle size distribution of the peat materials was measured with a standard sieve analysis (CEN, 2005). These data are provided for reference but have not been incorporated in any of the calculations.

The data of the measured moisture contents were fitted to formulas 1 and 2. The correlation data and the graphical representation of the fit were then studied and attempts were made to improve the formula 2 by adding empirically derived corrections.

RESULTS AND DISCUSSION

Properties of the unmixed constituents were measured (Table 1). The data for moisture content at laboratory container capacity are presented in Table 2. Finally the particle size distribution of the peat materials is shown in Table 3.

The results of formula (1) for moisture content show high correlation values in terms of R^2 (Table 4). For mixing ratios between 10 and 90%, the formula is, in absolute terms, still 10-20% of the mark (Fig. 1). The introduction of the extra density increase in formula 2 takes interstitial filling into account. This is a big improvement over the whole range of the mixes.

However, the moisture content in relatively wet materials such as peat-coir products is under-rated. It was now hypothesised that in all media, interstitial filling

would increase the number of small pores rather more than proportional and thus increase the moisture content more than formula 2 predicts. A correction factor in proportion to the density increase calculated by formula 2 was introduced as factor Ax. It was arbitrarily put at 0.15 i.e. 15% over the increase calculated by formula 2.

A small but distinct overrating of the moisture content remained when mixing with relatively dry materials as reed and flax. For these materials it was proposed that the moisture content of the unmixed material consisted for a large part of capillary unconnected moisture (residual water), which would drain when mixed with more capillary material. A second correction was therefore introduced to reduce the moisture content in proportion to the moisture content in the unmixed material and proportional to the amount used for mixing. It was arbitrarily put at 0.02 i.e. 2% over the moisture content of the unmixed material and the proportion used in the mix.

$$X_{1,2} = (C_1 * X_1 + C_2 * X_2) * (D_{x12} / (C_1 * D_{x1} + C_2 * D_{x2})) + A_x \quad (3)$$

$$X_{1,2} = (C_1 * X_1 + C_2 * X_2) * (D_{x12} / (C_1 * D_{x1} + C_2 * D_{x2})) + A_x - B_x \quad (4)$$

where X_{1,2} is the estimation of quality X in the mix of component 1 and 2; C₁ is the ratio of component 1 in the mix; C₂ is the ratio of component 2 in the mix; X₁ is quality X of component 1; X₂ is quality X of component 2; D_{x1,2} is the measured density of the mix; D_{x1} is the density of component 1; D_{x2} is the density of component 2; A_x is a general correction over the density increase; and B_x is a material specific correction on the initial moisture content

The corrections A_x and B_x in formulas 3 and 4 are hypothetical. A_x supposedly compensates for a decrease in pore size with increasing density. B_x may compensate for initially measured but not capillary connected water.

In conclusion formula 2 gives a fair estimate on a sound theoretical base. The increase in density of mixes may be calculated either by measuring the density increase of one or more test mixes, or from modeling a simplified particle size distribution, or from an empirically calculated relationship with particle size distribution parameters.

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Tables

Table 1. Basic properties of the unmixed constituents.

	Milled peat	Fraction 2	Torrefacted reed straw	Flax straw	Coir premix
Dry bulk density*	87.4	49.3	71.0	53.2	85.3
Moisture content*	79.0	46.0	12.9	20.6	51.0

Coir premix = 30% w/w coir fiber and 70% w/w milled Irish peat.

*According to CEN, 1998.

Table 2. Mixing ratio and moisture content at container capacity for four mixes.

Mixing ratio in % v/v		Moisture content at container capacity in % v/v*			
Milled peat (%)	Other material (%)	Fraction 1 (%)	Torrefied reed (%)	Flax (%)	Coir premix (%)
0	100	46	13	21	51
10	90	56	-	-	-
20	80	63	-	-	-
30	70	69	-	-	-
40	60	75	-	-	-
50	50	76	44	46	71
60	40	79	55	55	76
70	30	80	62	65	77
80	20	82	69	71	78
90	10	80	76	76	79
100	0	79	79	79	79

*According to CEN, 1998.

Table 3. Sieve analysis* of milled peat and fractioned sod peat ($n=3$).

Class limits in mm	>31,5	16-31,5	8-16	4-8	2-4	1-2	0.5-1	0-0.5
Milled peat		1	4	17	16	19	19	25
Fraction 1		1	16	30	19	13	9	11
Fraction 2		53	31	7	3	2	1	2

*According to CEN, 2005.

Table 4. R² correlation figures for the formulae.

Formula	Fraction 2	Reed	Flax	Coir premix
1= linear	0.887	0.996	0.994	0.953
2= 1+ density increase	0.979	0.995	0.989	0.981
3= 2+ pore decrease	0.980	0.993	0.989	0.994
4= 3+ residual water	0.980	0.999	0.999	0.994

Figures

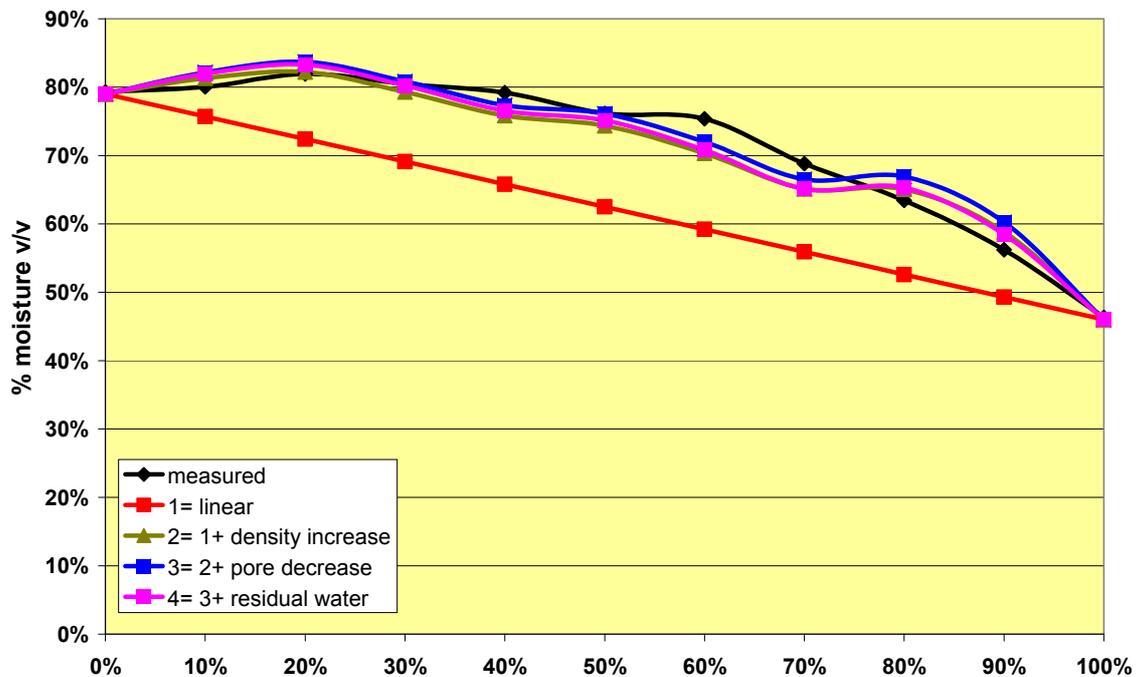


Fig. 1. Moisture content in various mixes of milled peat and fraction two sod peat as measured and as calculated with the different formulae (1= linear, 2= 1+ density increase, 3= 2+ pore decrease, 4= 3+ residual water). According to CEN, 1998.

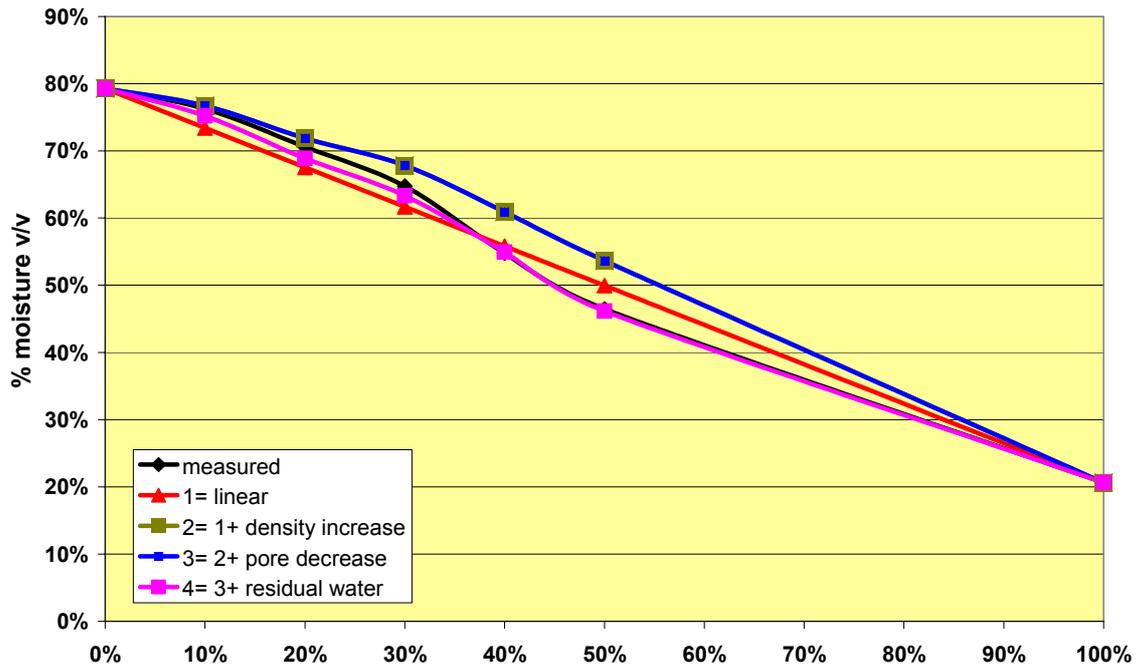


Fig. 2. Moisture content in various mixes of milled peat and flax straw as measured and as calculated with different formulae (1= linear, 2= 1+ density increase, 3= 2+ pore decrease, 4= 3+ residual water). According to CEN, 1998.