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The "Brazilian Test" as an indicator of workability for paddy soils in Vietnam

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Abstract

Farmers in Mekong delta prefer to till their soil in dry conditions when possible. They claim that crops establish and yield better when the field have been ploughed when dry compared to the wet preparation by puddling. Experiments were carried out to investigate the optimum workability range for the soils (heavy clay soils without any sand) in the area.

A simple laboratory test procedure to serve as an alternative to field testing was developed. The test assesses the behaviour of soil under compressive forces. Soil aggregates from 5 different soils in the area were compressed into small discs at various moisture content levels and aggregate size classes. After drying, the tensile strength of the discs was determined using the "Brazilian test".

It was found that the strength of the discs was strongly dependent on moisture content at compaction, aggregate size and compressive force, but also the organic matter content of the soils played an important role.

The Brazilian test provided useful information with respect to soil behaviour under tillage, in addition to the field tests.

Introduction

The Mekong Delta in south Vietnam is a major rice growing area in Southeast Asia. It covers an area of 3.9 millions ha, between longitudes 104° 30' to 107°E and latitudes 8°30' to 11°N. Except for some small hill areas, the Mekong Delta is a flat and low-lying area. The average altitude of the delta is about 2 meters above mean sea level.

The Delta has a monsoon tropical semi-equatorial climate, with a mean temperature of about 25 to 28° C (coolest months 23 to 25° C, warmest months 32 to 33° C). The mean annual rainfall is about 1600 mm for the whole Delta. In the Western part, rainfall is up to 2000-2500 mm; in the central part it is 1200-1500 mm, and towards the eastern part, it is 1500-1600 mm. There are two distinct seasons: the rainy season from May to November with about 90% of the total annual rainfall, and the dry season from December to April with a rainfall of about 10% of the total annual amount .

Upstream, the Delta is influenced by rivers, and downstream by the diurnal tidal movements of the Eastern Sea and the semi-diurnal tidal movement of the Western Sea. The annual rainfall combined with the high level of the Mekong River results in regular floods of 0.3 to 3 m during the wet season, mainly from August to November (with highest flood in September). The entire area is dry during the dry season (December to April). When the river flow is reduced, salt water intrudes the inland, especially in April and early May, affecting 2.1 millions ha in the coastal area.

Soils are tidal flat alluvial soils (Fluvisols; FAO-UNESCO, 1993). Depending on the physiographic region, farmers choose cultivation and tillage methods. Traditionally, farmers waited until the rains had saturated the land, and then used buffaloes to plough and harrow (to puddle the soil) in order to kill weeds and make a soft tilth for transplanting or preparing a

seedbed for broadcasting pre-geminated seeds. In some places, when the soil was submerged long enough, farmers did not need to puddle, but they could use a simple cutting tool "phan" to kill weeds before transplanting. Nowadays, with improved irrigation systems and other inputs, tractors are used. The cultivation method changed from transplanting to broadcasting, from one crop to two or three crops per year, and tractors substituted buffaloes. Traditional tillage was partly replaced by new systems, dry tillage, wet tillage and "mixed" tillage.

In *dry tillage* systems, all soil preparations are done when the fields are not inundated. In most of the cases, "big" (> 38 kW) tractors use a disc plough for primary tillage, followed by a disc harrow or a rotary tiller for seedbed preparation. Then the fields are inundated to create a mud layer for rice establishment. *Wet tillage* systems are systems where main tillage operations and seedbed preparations are done on inundated fields. In those cases, small (< 38 kW) tractors (equipped with rotary tillers or rollers and puddle wheels) or animals (pulling a local moldboard plough, comb harrow, wooden roller) are used. In *mixed tillage* systems the main tillage operations (mostly by big tractors) are done when the fields are dry, but seedbed preparations are done after the fields are inundated.

Farmers in the Mekong Delta prefer to till their soil in dry conditions when possible. They claim that crops establish and yield better when fields were ploughed when dry compared to the wet preparation by puddling. This is attributed to the better weed control and better resulting structure, even though the seedbed eventually is puddled again.

Experiments were carried out to investigate the optimum workability range for the soils in the area with respect to energy requirements of the operations and with respect to structure. Field experiments showed ranges of moisture content where energy consumption for the tillage operations was lowest, and (others) where the desired aggregate sizes were obtained (Long *et al.*, 2003).

When a tillage tool (plough) or transport device (wheel) generates a pressure on the soil body, it is compressed or strained. The soil body will be loosened or compacted, depending on several factors such as soil type, moisture status, soil aggregate size and soil-tool interaction. This behaviour is the basis of most workability tests. In this case, however, it was difficult to apply a simple test procedure in the laboratory to determine the optimum workability moisture range based on disturbed samples. Application of a "rule of thumb" of 60% of Field Capacity is subject to errors as there is a wide envelope of pF curves of these soils, depending on the degree of puddling.

Various laboratory methods have been developed to determine workability limits, e.g. based on soil consistency (Atterberg shrinkage and lower plastic limits), or based on the friability of the soil or the strength of clods or aggregates as a function of moisture content (Dexter, 2004; Watts *et al.*, 1996; Dexter and Bird, 2001; Hoogmoed *et al.*, 2003). The soils of the Mekong delta, however, possess a typical texture (Minh *et al.*, 1997), as they are composed of clay and silt, but have no sand fraction (see Table 1). Furthermore, these soils are seasonally subject to intense puddling followed by drying. This all makes it difficult to apply abovementioned methods.

The tensile strength of soil, however, has frequently been used as a basis for friability and workability determination. This is usually done by measuring natural aggregates. The tensile strength determined on cylindrical soil samples made from disturbed, moulded, compressed and dried soil material, has shown to be indicative of its behaviour under tillage as well (Imaz

Gurruchaga, 2005; Hoogmoed, 1999). This relatively simple test procedure was used to assess the characteristics of a number of soil types in the Mekong Delta.

The purpose of the experiments reported here was (a) to assess the effects of four basic soil factors (Soil organic matter, aggregate size, moisture content and compression stress) on the tensile strength of artificial samples, and (b) to evaluate its usefulness for the establishment of workability limits.

Materials and Methods

The soils under study are found in the center part of the Mekong delta, in the Vinhlong, Cantho and Haugiang provinces.

The soil collected in the field was left for air drying until reaching the friable stage, then it was gently broken down by hand and rubber hammer into various aggregate sizes. The soil then was left for further air drying. The air-dry soil was sieved and separated to the required aggregate sizes and stored in a sealed box. After determining the moisture content, batches of soil were weighed and put in a plastic bag and water was added with a fine spray to reach the pre-defined moisture level for the experiment. Then the bags were sealed and left for 24h to get uniform soil moisture distribution. Then soil samples were placed in rings of 50 mm diameter and 10 mm height (12 g of soil on air-dry basis) and compressed at the pre-set pressure level under a laboratory press.

The soil inside the ring was slowly oven dried at 70°C for 24h (to avoid cracks). The soil cylinders were carefully taken out of the rings, their diameter and length was measured. These soil cylinders were compressed until failure in the laboratory press. The maximum forces at failure were recorded. The tensile strength was calculated following the formula of (Dexter and Kroesbergen, 1985)

$$Y = 2 F / \pi d l$$

With

Y: tensile strength (kgf/cm²)

F: force at failure (kgf)

d: diameter of cylinder (cm)

l: length of cylinder (cm)

The experimental design was factorial with 4 factors.

Random factor: Soil organic matter (%) .

Fixed factor: Aggregate size (mm); Moisture content (%); Compression stress N/m².

Factor levels:

- Soil organic matter (OM) with 3 levels: 2.5, 5.0 and 8.9 %
- Aggregate size (aggr.) with 3 levels: 0.5, 3, 7 mm (classes 0-1, 2-4 and 6-8 mm).
- Moisture content (MC) with 3 levels: 26, 36; 41% (highest is around plastic limit).
- Compression stress (P) with 3 levels: 2, 4, 6 x 10⁵ N/m² (= 2; 4; 6 bar)

Each combination of factor-levels was five replications.

The total number of observations is: 3x3x3x3x5= 405 samples.

Results and Discussion

The soil characteristics are given in Table 1.

Table 1. Characteristics of the soils used in the Brazilian test. All values in %.

Soil	Sand*	Silt	Clay	OM	PL	SL
Hieunhon (Vinhlong)	0.6	42.1	57.3	8.1	42.0	23.0
Bacang (Vinhlong)	0.4	47.9	51.7	2.5	31.8	20.3
Vithanh B hor (Huagiang)	0.7	35.8	63.5	7.8	42.5	25.9
Vithanh A hor (Huagiang)	1.0	41.5	57.5	8.9	51.3	24.7
Sohafarm (Cantho)	0.2	53.3	46.5	5.0	42.7	24.7

* Sand: 0.05-2.0 mm; silt 0.002 – 0.05 mm; clay <0.002 mm; OM = organic matter

PL = moisture content at Plastic Limit; SL = moisture content at Shrinkage Limit

In Hienhon and Bacang, 3 crops of rice are grown per year, in Vitanh and at the Sohafarm 2 crops.

The results of the Brazilian test are given in Table 2 for the three most interesting situations, with three different OM levels.

Table 2. Summary of the results of the Brazilian tests. Tensile strength is in kgf/cm² or bar.

Location:		Bacang			Sohafarm			Vithanhg			Mean (P)	Mean (MC)
OM:		2.5%			5%			8.9%				
MC	P	AS (mm)			AS (mm)			AS (mm)				
		0.5	3	7	0.5	3	7	0.5	3	7		
26	2	0.5	0.5	0.4	0.3	0.3	0.3	0.1	0.1	0.1	0.4	0.9
	4	1.3	0.9	1.0	0.9	0.7	0.7	0.3	0.3	0.3	0.9	
	6	2.1	1.4	1.3	1.4	1.2	1.1	0.6	0.6	0.5	1.4	
36	2	4.3	4.1	3.8	1.4	1.4	0.7	0.6	0.4	0.4	2.6	3.7
	4	6.6	4.3	4.3	3.0	2.8	1.7	1.5	1.0	1.0	3.8	
	6	7.5	4.3	4.5	4.9	4.0	2.7	2.4	1.6	1.5	4.7	
41	2	5.3	3.0	3.2	2.8	2.7	1.6	1.2	0.9	0.9	3.1	4.3
	4	6.7	4.2	4.2	6.0	4.4	3.1	2.7	1.8	1.6	4.7	
	6	7.1	4.5	4.4	6.6	4.9	3.4	3.9	3.1	2.9	5.2	
Mean (AS)		4.6	3.0	3.0	3.0	2.5	1.7	1.5	1.1	1.0	3.0	
Mean (OM)		3.6			2.4			1.2				

OM = organic matter content (%); MC = moisture content during compression (% w/w); P = compression stress (bar); AS = average aggregate size (mm)

The statistical analysis using SPSS showed that all factors significantly influenced tensile strength. Tensile strength increases with pressure and moisture content but decreases with organic matter and aggregate size. Moisture content (MC) had the strongest influence on soil strength, followed by organic matter (OM), pressure (P), the least influencing was aggregate size (AS).

Interactions were found between all main factors. The strongest interaction was found between moisture content (MC) and organic matter (OM). At low moisture content (26%), the influence of aggregate size was not clear but with high moisture content, the tensile strength decreased when aggregate size increases. The highest tensile strengths were found with

samples generated from the soil with the lowest organic matter, at the smallest aggregate size (0.5mm), under highest pressure (6 kgf/cm²), at the highest moisture content.

The relationship with the practice of tillage in the field is as follows: the soil in Bacang has been put under intensive exploitation (3 crops/year) and has the lowest organic matter content. As a consequence, tillage may result in harder soil clods. In situations where farmers do excessive tillage so that the loosened layer contains a high percentage of small aggregates (0.5mm) then after rain, the surface layer becomes dense and massive. When this layer dries out by sun-dry it becomes very hard.

The plastic limit (PL) of Bacang soil is 32% and Sohafarm is 43% (see table 1). When moulding soil samples above or near plastic limit, the tensile strength becomes very high. This is also found in the field; when ploughing under wet conditions, the ploughed soil is not crumbled but becomes a long, “kneaded” band of soil. After drying, it becomes too hard to be broken down by secondary tillage especially when the implements are powered by buffaloes. The interactions effects between the factors are presented in Figure 1. Figures a,b, and c present interaction between aggregate size, moisture content and organic matter (OM). Figures d,e, and f illustrate the interaction between moisture content (MC), pressure and (P) aggregate size (AS).

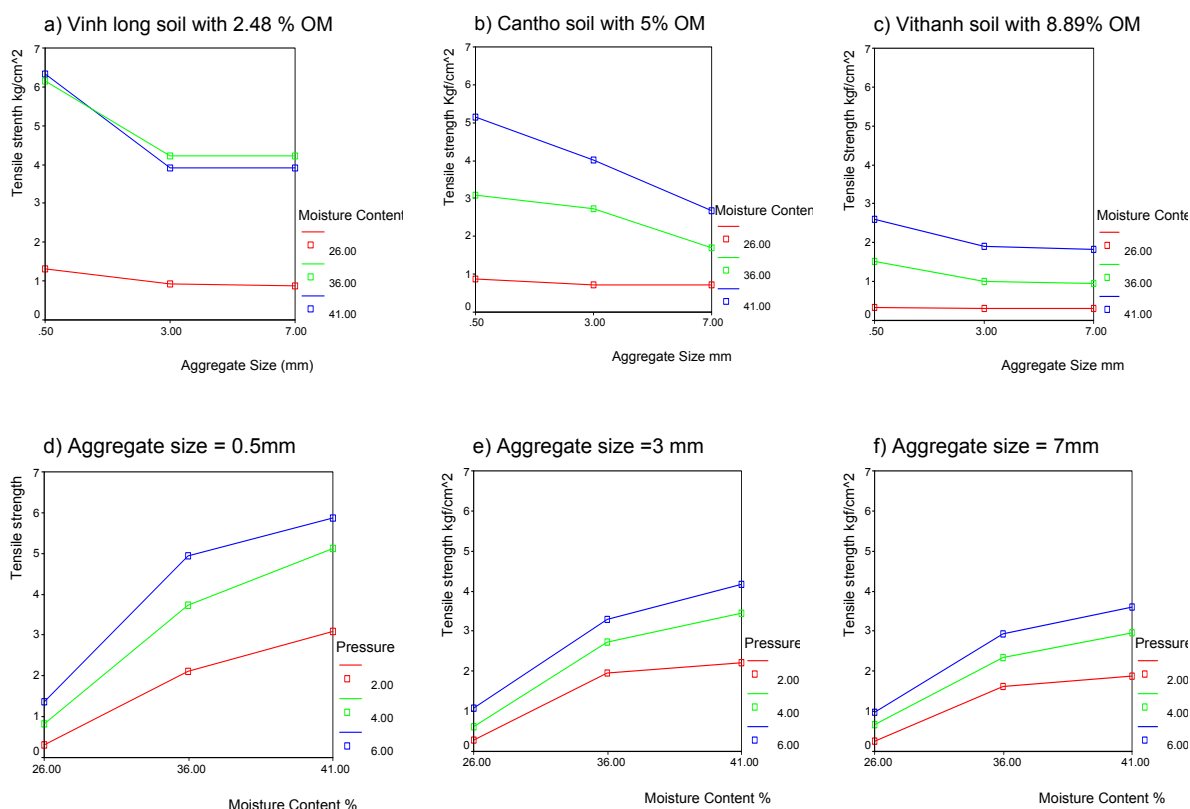


Figure 1 Interaction effect of various factors on soil tensile strength (Vinhlong = Bacang; Cantho = Sohafarm).

The outcome of these tests could be correlated well with the optimum moisture range found during field experiments (Long *et al*, 2003) and partly with the consistency limits determined in the laboratory

Conclusions

In the Brazilian test, moisture content had the strongest influence on soil strength, the second was organic matter, third was pressure and the least influencing was aggregate size and there are interaction effects between all main factors. The highest tensile strengths were found with samples generated from smallest aggregate size, under highest pressure, at high soil moisture around plastic limit and lowest organic matter.

Organic matter had a strong effect on the resulting strength of the soil cylinders. High organic matter contents will reduce the formation of hard clods under compressive forces, particularly in poor conditions (pulverised soil or high moisture content).

When soil is to be tilled in dry state, moisture content should be low, preferably 5-10% lower than the plastic limit.

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