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STRUCTURE ABILITY OF FINE TEXTURED RED SOILS IN NORTH LIBYA

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A b s t r a c t. The aim of this work was to analyse structure resistance, capillary rise, mechanical strength and other physical properties in fine textured soil in North Libya. The examination of these characteristics was carried out on laboratory modelled soil aggregates (1 cm^3 volume) with special methods developed in the Soil Science Department of the Agricultural University in Poznań.

The samples were taken from red soils (*Terra Rossa*) occurring in the Cyreneica Region. All these soils belong to clayey textured group. Investigations have shown surprisingly low resistance to dynamic and static water action for dry aggregates and very high for moist ones. Percentage of 'secondary aggregation' is very high, in most cases exceeds 80 % of total soil mass. The secondary microaggregates with diameter of 3-1 mm and 1-0.5 mm predominate. The maximum capillary water capacity of soil aggregate models in 'free swelling' conditions is so high that it is incomparable to soil porosity.

K e y w o r d s: red soil, soil aggregates, water resistance.

INTRODUCTION

The significant part of North Libya, along the Mediterranean Sea shore, is covered by specific soils called *Terra-Rossa* soils. These soils are characterized by intensive red colour and, as a rule, high content of clay. They developed on a residium material of limestones and the main role was played by the rubification processes, which consist of the conversion of iron compounds to Fe_2O_3.

At present, due to shortage of precipitation during spring and summer, the intensive agricultural use of these soils is only possible under irrigation. The effectiveness of production on irrigated land significantly depends on soil properties, especially structure ability, capillary water capacity, resistance of aggregates on dynamic as well as static water action.

Unfortunatelly, these specific soils are not well recognized from a genetic point of view, soil properties or 'behaviour' under irrigation.

This paper deals with structure ability and other physico-chemical properties of some Terra-Rossa soils in North Libya.

MATERIAL AND METHODS

The soil samples were collected during a soil survey in the north part of Libya. The profiles 1, 2 and 3 were located on the Cyreneica Peninsula near Al Bayda, but profile 4 from the Benghazi region. All these soils have similar morphological characteristics, reddish colour surface horizons, which contain about 1 % of organic matter, moderately developed fine and medium subangular blocky and granular structure and have no distinct developed genetic horizons with diffuse boundary between them. More data concerning genesis, classification and other features of these soils as well as natural conditions of the investigated area will be published elsewhere.

Soil samples taken from soil profiles were air-dried and then sieved through a sieve with a mesh size of 2 mm.

The structure ability and other specific physical characteristics were determined by special laboratory methods developed in the Soil Science Department, University of Agriculture in Poznań and described in detail by Rząsa and Owczarzak [3].

Aggregate models - 1 cm^3 - have a cylindrical shape with a base of 1 cm^2 and 1 cm high. The models are prepared from air-dry soil mass mixed with distilled water in amount which will ensure a hard plastic consistency. The soil mass is forced into a mould and sampled by a special cutter.

The water resistance of soil aggregate models on dynamic water action was carried out on a special apparatus with a device for feeding 0.05 ml water drops, which fall down from 1 m height and exert an impact on the spherical surface with kinetic energy of $4.905 \cdot 10^{-4}$ J. The results determining the resistance to dynamic water action can be expressed as the number of standardized drops (0.05 g), or in values of kinetic energy (J).

The resistance (of soil aggregate models) to static water action was determined by the measurement of the 'soaking time' of aggregates submerged in water. The aggregates are placed horizontally on the stretched nylon threads and soaking time is counted from the moment when water contacts the aggregates.

The 'secondary aggregation' (after dynamic and static water action) was determined by a sieving method using a set of sieves with 7, 3, 1, 0.5, and 0.25 mm mesh sizes. The disintegrated soil materials were put on a set of sieves, than submerged in water and afterwards slowly raised and lowered to cause separation.

To determine the minimum and maximum capillary water capacity of model soil aggregates, they were placed vertically on filter paper which adhers to a filtration pad. The filtration pads were placed in a flat glass vessel filled with water up to the level of a few milimeters below the filter paper.

The 'minimal capacity' is when the water front reaches the upper of the aggregate. The 'maximal capacity' is when the water appears on the upper surface of the aggregates in the form of light reflecting menisci. The water content at these two capacities were determined by dryer-balance method.

The mechanical strength of soil model aggregates were measured using an LRu apparatus, especially adopted for crushing/compression strength of 1 cm^3 aggregates.

The other physical and chemical characteristics of investigated soils (soil texture, maximal hygroscopic water, plasticity limit, bulk density, porosity and $CaCO_3$ content) were determined by common methods [1].

RESULTS

The soil texture and other basic physicochemical properties of investigated soils are shown in Tables 1 and 2. Most of these soils (profiles 1, 2 and 3) contain a very high amount of clay particles (55-77 %), so they belong to clayey textural group. Some of them can be classified as heavy clay because they contain more than 60 % of clay. Only some layers of profile 4, located in Benghazi, show moderate texture: clay loam and loam.

From the other basic properties of investigated soil it is worth pointing out the relatively low bulk density (1.2-1.4 g/cm^3) and high porosity (44-52 %). These characteristics are closely connected with moderately developed natural structure. Very high maximal hygroscopic water capacity, which in most cases amounts to 17-22 %, and plastic limit, ranging from 24 to 35 %, are much higher than in heavy textured Polish soils [5]. The exception in these characteristics is profile 4.

Resistance of air-dry soil aggregate models on static action was generally low (Table 3). Time of aggregate-disintegration varies from 82 to 195 s (with the exception of soil aggregates from A horizon in profile 3). Such results, according to the 10-grade scale proposed by Rząsa and Owczarzak [3,4], put these soils on 2nd or 3rd grade ('very low' or 'medium low' resistance).

Resistance of air-dry aggregate models to dynamic water action (Table 4) is also relatively low and corresponds 3rd to 5th grade ('medium low', 'low' and 'medium'), of water resistance in the above mentioned scale.

Table 1. Soil texture and mechanical strength of air-dry aggregates

Place and No. of profile	Horizon	Depth [cm]	Particle size distribution [%] sand 2-0.05 mm	silt 0.05-0.002 mm	clay <0.002 mm	Textural group	Mechanical strength [MPa]
Ras al hilal	A	0- 37	6.5	29.5	64.0	C	9.9
1	(B)	37- 80	8.1	26.0	65.9	C	3.9
	C	80-120	12.7	33.7	53.6	C	5.4
Ras al hilal	A	0- 26	6.6	32.7	60.7	C	9.1
2	(B)	26- 55	7.3	27.5	65.2	C	4.1
	C	55-100	9.7	27.1	63.2	C	5.3
Satyach	A	0- 18	22.0	19.6	58.4	C	3.7
3	(B)	18- 55	16.7	20.4	62.9	C	4.7
	C	55-125	12.0	11.0	77.0	C	4.5
Benghazi	A	0- 30	35.9	29.0	35.1	CL	3.5
4	(B)	30- 60	43.2	33.1	23.7	L	2.3
	C	60-100	22.2	36.2	41.6	C	3.9

Table 2. Some physico-chemical properties of investigated soils

Number of profile	Horizon	Depth [cm]	Bulk density [g/cm^3]	Porosity [%, v/v]	$CaCO_3$ [%, w/w]	Max. hygr. water [%, w/w]	Plastic limit [%, w/w]
1	A	0 - 37	1.48	39.1	0.9	15.8	25.1
	(B)	37 - 80	1.32	46.6	4.1	17.3	24.1
	C	80 - 120	1.39	44.0	8.1	17.3	22.7
2	A	0 - 26	1.20	51.1	0.6	15.0	23.6
	(B)	26 - 55	1.29	47.6	0.6	16.2	25.8
	C	55 - 100	1.20	51.4	0.0	17.6	25.8
3	A	0 - 18	1.36	44.9	0.0	14.9	29.5
	(B)	18 - 55	1.24	49.7	0.0	19.9	36.4
	C	55 - 125	1.23	49.3	0.0	22.2	39.0
4	A	0 - 30	1.28	49.0	13.6	16.0	15.9
	(B)	30 - 60	1.21	51.7	8.0	13.3	17.0
	C	60 - 100	1.21	51.9	13.8	11.8	19.0

The water resistance for wet soil aggregates was totally different. These aggregate models, prepared from soil mass at moisture corresponding to double maximal hygroscopic water, have shown a 10th grade of water resistance ('full resistance'). For static water action the disintegrating-time was more than 24 h, but for dynamic water action the disintegrating kinetic energy exceeds 1000 J. These 'phenomena' of low resistance for dry aggregates and extremely high for moist ones show that water plays a very important role in the compaction and cohesion of soil particles or aggregates.

Knowledge of such 'behaviour' of soil aggregates depending on moisture status is very important from a practical point of view, especially under irrigated agriculture production.

Table 3. Disintegrating-time and secondary aggregation after static water action on air-dry* aggregates

Number of profile	Horizon	Depth [cm]	Disint. time [s]	Percentage of aggregates collected on sieves [dia. mm]						Percentage of aggregates [dia. mm]	
				7	5	3	1	0.5	0.25	<0.25	>0.25
1	A	0- 37	82	0.0	0.0	0.9	50.7	22.9	12.7	12.8	87.2
	(B)	37- 80	97	0.0	0.0	1.2	38.1	31.3	15.7	13.7	86.3
	C	80-120	153	0.0	0.0	2.4	53.0	21.1	11.0	12.5	87.5
2	A	0- 26	125	0.0	0.0	0.0	24.7	30.6	20.0	24.7	75.3
	(B)	26- 55	125	0.0	0.0	0.5	26.7	35.2	23.8	13.8	86.2
	C	55-100	77	0.0	0.0	0.4	22.6	29.4	33.0	14.6	85.4
3	A	0- 18	1170	2.9	0.0	16.9	50.6	11.7	10.3	7.6	92.4
	(B)	18- 55	195	0.0	0.0	0.5	49.1	13.2	29.7	7.5	92.5
	C	55-125	130	0.0	0.0	0.0	13.7	36.0	28.2	22.1	77.9
4	A	0- 30	95	0.0	0.0	0.9	30.3	33.2	24.7	10.9	89.1
	(B)	30- 60	120	0.0	0.0	0.0	27.3	33.0	19.5	20.2	79.8
	C	60-100	125	0.0	0.0	1.9	46.7	29.1	20.9	1.4	98.6

*Moist aggregates did not disintegrate after 24 h.

Table 4. Disintegrating-energy and secondary aggregation after dynamic water action on air-dry* aggregates

Number of profile	Horizon	Depth [cm]	Disint. time [s]	Percentage of aggregates collected on sieves [dia. mm]						Percentage of aggregates [dia. mm]	
				7	5	3	1	0.5	0.25	<0.25	>0.25
1	A	0- 37	5.95	0.0	0.0	0.4	39.9	27.0	16.1	16.6	83.4
	(B)	37- 80	4.90	0.0	0.0	0.5	31.1	35.2	18.3	14.9	85.1
	C	80-120	6.86	0.0	0.0	1.3	42.4	27.1	19.9	9.3	90.7
2	A	0- 26	7.01	0.0	0.0	0.0	40.2	38.9	20.1	10.3	89.2
	(B)	26- 55	5.54	0.0	0.0	2.5	30.6	31.4	21.2	14.3	85.7
	C	55-100	7.35	0.0	0.0	0.6	35.9	28.9	25.6	9.0	91.0
3	A	0- 18	32.37	0.0	0.0	12.5	54.0	12.8	8.1	12.6	87.4
	(B)	18- 55	12.36	0.0	0.0	1.4	47.9	27.1	12.9	10.7	89.3
	C	55-125	5.83	0.0	0.0	1.8	18.4	34.1	33.4	12.3	87.7
4	A	0- 30	35.70	0.0	0.0	2.2	2.2	15.0	29.2	40.8	50.2
	(B)	30- 60	19.17	0.0	0.0	0.0	0.0	28.0	2.3	69.7	30.3
	C	60-100	18.94	0.0	0.0	0.0	10.2	34.2	27.4	28.2	71.8

*Moist aggregates did not disintegrate after 20 000 water drops (> 1 000 $J \cdot 10^{-2}$).

A very important characteristic in this matter is the ability for secondary aggregation. At this term we understand 'composition of soil mass' after disintegration of soil macro-aggregates (in our experiments - 1 cm^3 volume). From results shown in Tables 3 and 4 it can be found that aggregate models have disintegrated to secondary meso- and micro-aggregates with a diameter greater than 0.25 mm in above 80 %, but only about 20 % to particles or aggregates with a smaller size. Within the secondary aggregates, which were relatively stable, have

Table 5. The minimal and maximal water capillary capacities of air-dry aggregates

Number of profile	Horizon	Depth [cm]	Minimal		Maximal	
			Time [s]	Moisture [%, v/v]	Time [s]	Moisture [%, v/v]
1	A	0-37	115	47.5	3600	72.6
	(B)	37-80	117	45.8	3600	69.3
	C	80-120	180	53.2	3600	62.0
2	A	0-26	122	47.4	3600	59.4
	(B)	26-55	108	37.8	3600	63.9
	C	55-100	148	48.4	3600	62.9
3	A	0-18	367	34.6	3600	53.8
	(B)	18-55	328	43.6	3600	63.9
	C	55-125	155	68.3	3600	89.9
4	A	0-30	375	31.0	3600	49.9
	(B)	30-60	350	42.5	3600	61.3
	C	60-100	305	46.1	3600	61.6

dominated aggregates with diameter of 3-1 and 1-0.5 mm. Such a high secondary aggregation was not found in any Polish soils, even in rendzinas with moderate clay content [4]. Only soil material from profile 4 with medium texture showed much less secondary aggregation.

The crashing strength of soil aggregate models (Table 1) ranged from 2.3 to 9.9 MPa. These results are comparable with aggregate strength of some Polish soils: medium textured alluvial soils and clay-loamy soils [2].

The maximal capillary water capacity of models soil aggregates was much higher than values of total porosity of the soil (Tables 2 and 5). These surprising results indicate that in 'free swelling' conditions, the changes of aggregate volumes can be very big.

It must be pointed out that soil aggregates did not disintegrate after maximal capillary water rising (3 600 s), whereas analogical aggregate models submerge in water, during static water action measurment, disintegrated already within 100-200 s. Similar results have been found in some medium and heavy textured Polish soils [4].

CONCLUSIONS

The most relevant findings of this work can be generalized in a few items.

1. The most of red soils of North Libya were characterized by high content of clay (often exeeds 60 %) and medium developed, mostly fine and medium, subangular blocky and granular natural structure.

2. The model soil aggregates show in laboratory experiments surprisingly low water resistance of air-dry aggregates and extremely high of moist ones. The 'secondary aggregation', after disintegration of air-dry aggregates, is very high. More than 80 % of soil mass was as meso- and micro-aggregates with a diameter > 0.25 mm.

3. The maximal capillary water capacity of soil aggregates in 'free swelling' conditions is much higher than values of total porosity of soil at field conditions.

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