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Assessment of the compressibility behaviors of some Barind Clay samples collected from Narhatta area, Bogra

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Abstract

One of the major problems of concern to the soils engineer is predicting the amount of volume change or settlement which will occur in a soil when it is subjected to stresses. The compressibility is found to be the intrinsic property of soils to evaluate settlement under a given loading. In this research, the compressibility characteristics of some Barind Clay soils of Narhatta area, Bogra are evaluated based on oedometer consolidation test. The studied soil is low to medium plasticity silt dominated clay. The consolidation test result suggests that the analyzed soils might be normally consolidated to over-consolidated in nature. The co-efficient of volume compressibility (m_V) values lie between 0.0317 to 0.2414 m^2/MN and the compression index (C_C) values range from 0.0051 to 0.3654. Both values suggest that the studied soils are hard to plastic, low to medium compressibility in nature and having slow rate of settlement. Therefore, the studied Barind Clay soils might have good engineering mechanical properties and suitable for building foundations.

Keywords: Barind Clay, compression index, volume compressibility, Narhatta

Introduction

The researchers and geotechnical engineers are always interested to know the compressibility behavior of soil. In present day, different types of structural failure or damage is one of the vital growing structural and financial problems in the world mainly in the developing countries like Bangladesh. These structural failures are taking place mostly because of different types of settlements which is closely related with the geotechnical properties of soils. Therefore, one of the major problems of concern to the soils engineer is predicting the amount of volume change or settlement which will occur in a soil when it is subjected to stresses. The compressibility behavior of soil is found to be useful in predicting the settlement of structures (MACCHECHNIE 1967). It has increasingly been studied in the last decades (COERATO & LUTENEGGER 2004; HONG *et al.* 2012; LIU *et al.* 2013; ZHANG *et al.* 2017; LYU *et al.* 2020). One-dimensional consolidation test is generally carried out to determine the compressibility behavior of fine grained soils which played key roles in the design/construction of civil engineering

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infrastructures (SCHIFFMAN *et al.* 1984). Soil consolidation refers to the reduction in volume of a saturated soil when acted on by a static load over a long period and it is the important geotechnical problems for construction of infrastructure (BONG *et al.* 2014). It is a time-dependent volume change (compression) process induced by both dissipation of excess pore water pressure and reorientation of mineral grains (FENG 2010).

The study area Narhatta of Kahaloo Upazila, Bogra is covered by reddish brown soil of Barind Clay which is a south-eastern part of Barind Tract, a Pleistocene terrace of the Bengal Basin (Fig. 1). The characteristic red color of these soils is formed due to the persistent weathering of the iron rich sediments and hence locally known as 'red clay'. These red clay soils are in-situ developed soils and classified as residual soils which show different nature from the other soils of Bangladesh (MONSUR 1995). Furthermore, the area is generally experiences tropical to sub-tropical monsoon

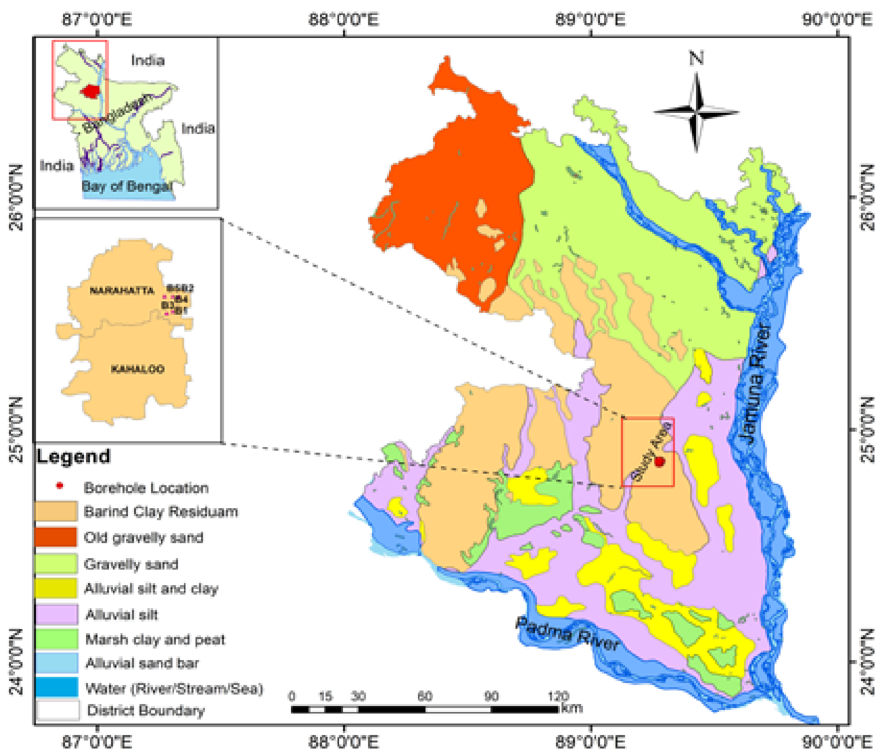

Fig. 1. Location map of the study area (modified after ALAM *et al.* 1990).

climate characterized by wide seasonal variations in rainfall, warm to hot temperatures and high humidity which is one of the main geological factors in the formation process of the residual soils (KHATUN *et al.* 2016). These soil properties vary from region to region due to their heterogeneous nature and highly variable degree of weathering, climatic and topographic conditions and the nature of parent materials (RAHARDJO *et al.* 2000).

In Bangladesh, a number of authors (HAQUE 1994; SIDDIQUE & SAFIULLAH 1995; HOSSAIN & ISLAM 1997; NAIRUZZAMAN *et al.* 2000; HOSSAIN 2001; SERAJUDDIN *et al.* 2001; HAQUE *et al.* 2013) investigated the engineering and geotechnical properties of Madhupur Clay soils collected from different locations of Madhupur Tract, another Pleistocene terrace of the Bengal Basin. However, very few detailed works of the engineering geological properties of Barind Clay is reported so far except few commercial works that gives the wide range of scope of research. Furthermore, it is expected that huge constructions and development work will be done in near future in the study area. The main purpose of this research is to evaluate the compressibility characteristics of Barind Clay soils of Narhatta area, Bogra.

Materials and Methods

The Authority of "Housing and Building Research Institute (HBRI)" at Sher-e-Banglanagar, Dhaka, under the Ministry of Housing & Public Works, carried out a detailed soil investigation program for the construction of a Radio Mast at Narhatta of Kahaloo Upazila, Bogra. Five boring, each extending to the depth of 50'-0" have been selected and executed as per direction of the proper authority. The borehole locations are shown in Fig. 1. The method of wash boring technique was used as a means of advancing the borehole to enable the tube samples to be taken. The disturbed soil samples have been collected at an interval of 5'0" depth throughout the drilled depth of each borehole. The above soil samples have been collected simultaneously by using split spoon sampler with the performance of the standard penetration test (SPT). The required specimen of soil samples in the undisturbed state have been obtained with the help of thin open Shelby tubes particularly from the top layer of the cohesive soil (clay). The geotechnical parameters were determined in the soil test laboratory in the Housing and Building Research Institute (HBRI) according to ASTM (1974). The data generated by the Housing and Building Research Institute (HBRI) were collected for this research work.

Results and Discussions

Basic properties of the soil

The basic engineering properties are the most important factor to identifiy and determine the behavior of clay. Based on SPT values, the top layer (up to 10 ft depth) is cohesive and medium stiff to stiff in nature which is good for low load bearing structures. Below that depth the soil is non-cohesive, having medium to dense state is very good strength for moderate load bearing structure. The studied soils are silt dominated which contains 54.40 to 80.60% silt with 9.40 to 41.30% sand and 4 to 14.10% clay. It may be defined as sandy silt. Sand percentages are increased with increasing depth whereas silt and clay values are decreased with depth. Moisture content ranges from 13.96 to 33.45% and the specific gravity falls within a range of 2.61 to 2.69. It is found that both values are decreased with increasing depth.

The tested soils show low to moderate liquid-plastic limit values; the liquid limit values range from 27.0 to 41.0% and plastic limit values range from 10.0 to 21.05%. The plasticity index values lie between 13.95% and 20.64%. The obtained results suggest that the top layer of the studied soils (up to 10 ft depth) are cohesive and can be classified as low to intermediate plasticity soil and show medium to low swell potential according to VANDER MERWE (1964), SEED *et al.* (1962) and BS 5930 (1981) whereas the soils below the 10 ft depth are non-cohesive in nature and named as sandy silt.

Compressibility Behaviors

The compressibility characteristics of some selected samples from five boreholes of the studied area have been determined by the use of standard procedure and the results are presented in terms of void ratio versus P´ curve, co-efficient of volume compressibility (m_V) and compression index (C_C).

Void ratio (e) versus log P´ curves

The void ratio (e) versus Pressure (kPa) curves for the samples of five boreholes of the Barind Clay soils of the studied area are shown in Fig. 2, where void ratio (e) is plotted against effective pressure (P´) (in log scale) from a single increment test for each sample. It can be seen that the void ratio value decreased in each case with increasing effective pressure.

The change of void ratio start to the end of the test for the pressure increment is small which indicates that the rate of settlement is slow and might be due to the cementation of free iron oxide in the studied soils. These figures also show more or less similar compression pattern by applying load. The shapes of the curves are related to the stress history of the clay (CRAIG 1987). The apparent pre-consolidation pressure (P'_C) of the studied soils ranges from 70-145 kPa and the effective overburden pressure (σ'_V) ranges from 32-55 kPa. This pre-consolidation pressure might be developed due to effective overburden pressure and microstructural bonding of the soil (HOSSAIN 2001; SAYEM *et al.* 2012; SHOME *et al.* 2014). Therefore, the analyzed soils might be normally consolidated to over-consolidated in nature. Due to the weathering process and to less extent to the reduction in stress, the soil appears to be over-consolidated in nature (MOHAMEDZEIN & ABOUD 2006).

Co-efficient of volume compressibility (m_V)

The co-efficient of volume compressibility (m_V) of the selected undisturbed samples of the studied soils have been calculated for each pressure increment (Table 1).

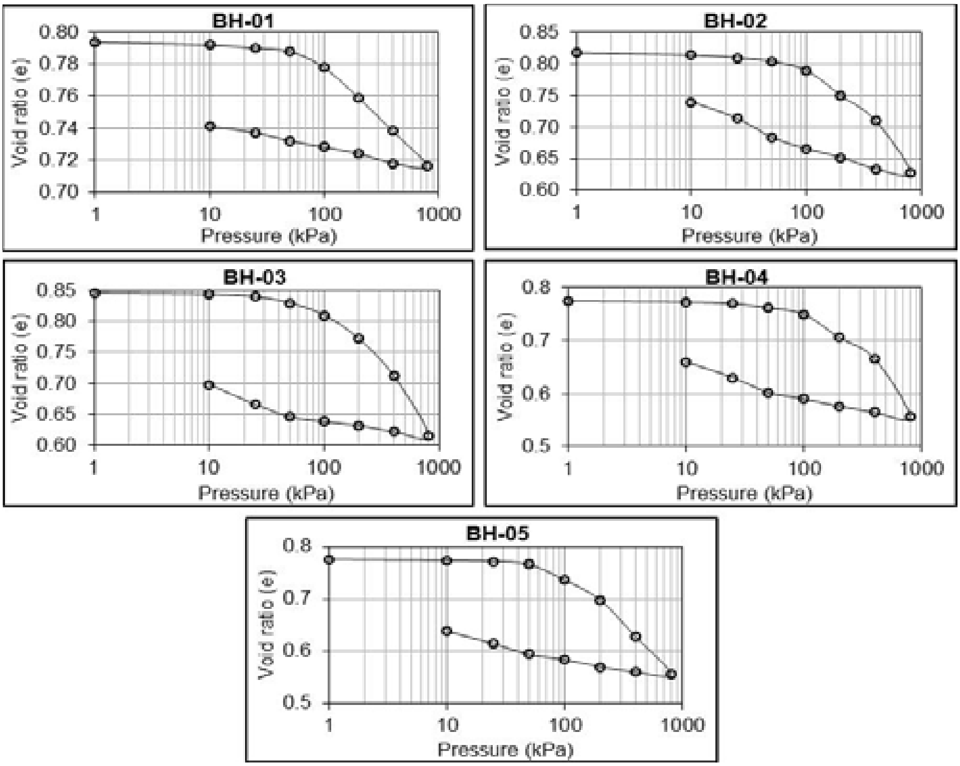

Fig. 2. Void ratio (e) vs pressure (kPa) curve for different borehole samples.

The m_v values show very low that range from 0.0317 to 0.2414 m^2/MN and vary with pressure increments as well as different locations. This variation may be due to the variation of the amount of cementing materials and grain size at different locations. The relationship between m_v values with consolidation pressures and void ratio are shown in Fig. 3. It is found that the m_v value decreased with increasing consolidation pressure but the relationship between m_v and void ratio is very poor. With increasing pressure, the particles are converged closer to each other and the soil samples are compacted to more stiff structure.

SMITH (1998) mentioned some typical values of m_v (m^2/MN) for different types of clay: hard clay (boulder clay) 0.0625 to 0.125; stiff clay 0.125 to 0.25; plastic clay (NC alluvial clays) 0.25 to 2.0 and for peat 2.0 to 10.0. Based on the co-efficient of volume compressibility values (m^2/MN), HEAD (1982) and LAMBE & WHITMAN (2000) classified clays, which are- very high >1.5, high 0.3 to 1.5, medium 0.1 to 0.3, low 0.05 to 0.1 and very low <0.05. Therefore, the obtained m_v values suggest that the studied soils are hard to plastic clay, medium to very low compressibility in nature according to SMITH (1998), HEAD (1982) and LAMBE & WHITMAN (2000).

Table 1. Co-efficient of volume compressibility (m_v) values of the studied area.

Pressure (kPa)	**Co-efficient of volume compressibility (m^2/MN)**				
	BH-1	BH-2	BH-3	BH-4	BH-5
10	0.1115	0.2200	0.1083	0.1127	0.1126
25	0.0744	0.1470	0.1446	0.1128	0.0752
50	0.0447	0.1326	0.2174	0.1808	0.1354
100	0.1119	0.1552	0.2186	0.1362	0.2098
200	0.1069	0.2235	0.2099	0.2414	0.2189
400	0.0597	0.1143	0.1693	0.1172	0.2061
800	0.0317	0.1199	0.1402	0.1651	0.1106
Average	*0.0772*	*0.1589*	*0.1726*	*0.1517*	*0.1512*

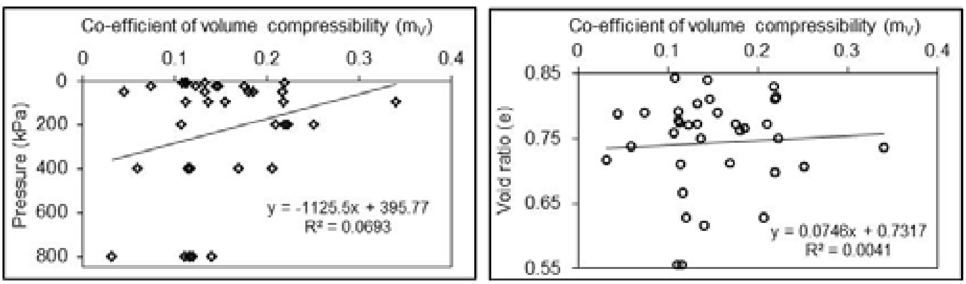

Fig. 3. Relationship between m_v values with consolidation pressures and void ratio.

The compressibility characteristic of fine-grained residual soils influenced by the presence of iron oxide and depended on the structural arrangement of the soil particles and their adjacent bonding (BLIGHT 1988; RAO *et al.* 1988; VENKATRAMAIAH 2006). Therefore, the obtained medium to low compressibility behaviors might be due to the microfabric and bonding strength of the studied soils. HOBBS *et al.* (1988) reported the m_v value for tropical red clay of West Java, Indonesia ranges from 0.03 to 1.0 m^2/MN. CARTER & BENTLEY (1991) quoted a value of 0.05-0.1 m^2/MN for low compressibility very stiff tropical clay and a value of 0.1-0.3 m^2/MN value for medium compressibility firm tropical red clays. The m_v values for Madhupur Clay Formation of Dhaka range from 0.0048 to 0.6886 m^2/MN (HAQUE 1994), 0.0016 to 0.3633 m^2/MN (NAIRUZZAMAN *et al.* 2000) and 0.04 to 0.24 m^2/MN (HOSSAIN 2001). The obtained m_v values are in well agreement with the values quoted by HOBBS *et al.* (1998) and HOSSAIN (2001).

Compression Index (C_C)

The compression Index (C_C) values of the selected samples have been determined and the values are shown in Table 2. The compression Index (C_C) value of the studied samples ranges from 0.0051 to 0.3654. The variation of C_C values with consolidation pressures, void ratio and m_v values for different boreholes are shown in Fig. 4. It is found that C_C values increased with increasing pressure but decreased with void ratio. Though the relationship between C_C and m_v is very poor, the C_C value slightly increased with m_v.

Table 2. Compression Index (C_C) values of the studied area.

Pressure (kPa)	Compression Index (C_C)				
	BH-1	BH-2	BH-3	BH-4	BH-5
25	0.0051	0.0101	0.0122	0.0075	0.0053
50	0.0066	0.0199	0.0332	0.0266	0.0199
100	0.0332	0.0465	0.0664	0.0399	0.0997
200	0.0631	0.1329	0.1262	0.1462	0.1262
400	0.0698	0.1326	0.1993	0.1329	0.2325
800	0.0731	0.2724	0.3189	0.3654	0.2392
Average	*0.0418*	*0.1024*	*0.1257*	*0.1197*	*0.1204*

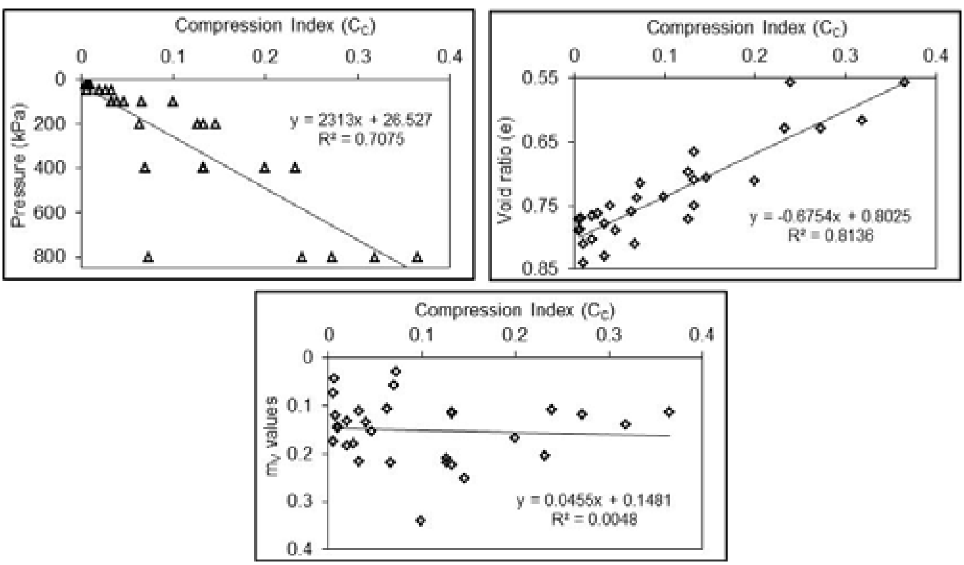

Fig. 4. Relationship between C_C with consolidation pressures, void ratio and m_v values.

HARDY (1965) studied the heavily consolidated clays of Canada and mentioned that the compression index ranges from 0.03 to 1.34. SERAJUDDIN (1998) reported the compression index for the soil of north-west zone (Dinajpur, Rajshahi, Bogra, Pabna) of Bangladesh is 0.10 to 0.64. NAIRUZZAMAN *et al.* (2000) mentioned that the compression index (C_C) values vary from 0.0962 to 0.1784 with an average value of

0.129 for the Madhupur Clay of Greater Dhaka city. SERAJUDDIN et al. (2001) pointed out that the compression index of majority of Dhaka city is within 0.10 to 0.20. The obtained compression index (C_C) values for the studied soils are close to the values quoted by SERAJUDDIN (1998).

The 'Code for Design of Building Foundation (GB50007-2011)' has noted that if the C_C value is larger, the void ratio and the compressibility are also higher. Generally, as $C_c< 0.2$, soil belongs to low compressibility; $C_c= 0.2$ to 0.4, soil is medium compressibility, and $C_c> 0.4$, soil is of high compressibility. Therefore, the analyzed Barind Clay soils can be classified as low to medium compressibility soil and the observation is consistent with the m_v values. On the other hand, HEAD (1982) mentioned some typical values of C_C for different types of clays. He quoted a compression index value of 0.2 to 0.8 for medium to low plasticity clay and a C_C value of up to 2.6 for montmorillonite clay. Therefore, the obtained C_C values suggest that the study soil is medium to low plasticity clay which is also consistent with the index properties of the studied soils.

Conclusions

The main purpose of this research is to evaluate the compressibility characteristics of some Barind Clay soils of Narhatta, Bogra area. The studied soils are silt dominated clay and can be classified as low to intermediate plasticity clay. Based on the consolidation test, the analyzed soils might be normally consolidated to over-consolidated in nature. The m_v values show very low that range from 0.0317 to 0.2414 m^2/MN and vary with pressure increments as well as different locations. The obtained m_v values suggest that the studied soils are hard to plastic clay, medium to low compressibility in nature. The compression index (C_C) values range from 0.0051 to 0.3654 and increased with increasing pressure but decreased with void ratio. The obtained C_C values suggest that the analyzed Barind Clay soils can be classified as low to medium compressibility soil and the observation is consistent with the m_v. The overall consolidation characteristics including volume compressibility, compression index along with consistency limit values suggest that the analyzed soils can be classified as low to medium plasticity soil and of low to medium compressibility.

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বগুড়া জেলার নরহাট্টা এলাকার বরেন্দ্র কর্দম নমুনার সংকোচনশীলতা মূল্যায়ন

হুসাইন মোঃ সায়েম, মুকিম আহমেদ রিজভী, মাহমুদা খাতুন ও মোঃ হাসান ইমাম

সারসংক্ষেপ

সংকোচনশীলতা মৃত্তিকার একটি সহজাত বৈশিষ্ট্য। ভূ-প্রকৌশল বিষয়ক গবেষকগণ সর্বদা মৃত্তিকার সংকোচনশীলতা পর্যবেক্ষণ করে থাকেন। তার প্রধান কারণ হলো সংকোচনশীলতার জন্যই মূলত বিভিন্ন রকম অবকাঠামো হঠাৎ ধ্বসে পড়ে এবং এর ফলে অর্থনৈতিক ক্ষতি যেমন সাধিত হয়, তেমনি মানুষের জীবন বিপন্ন হয়। এ গবেষণা প্রবন্ধের মূল উদ্দেশ্য হলো বগুড়া জেলার নরহাট্টা এলাকার বরেন্দ্র কর্দম মৃত্তিকার নমুনার সংকোচন বৈশিষ্ট্য পর্যবেক্ষণ ও মূল্যায়ন করা, যাতে উক্ত এলাকার জনসাধারন অবকাঠামো ধ্বসজনিত দুর্যোগ ও দুর্ঘটনা থেকে রক্ষা পেতে পারে। গবেষণায় দেখা যায় যে, উক্ত এলাকার মৃত্তিকা মূলতঃ পলল সমৃদ্ধ কর্দম মৃত্তিকা যা নিম্ন থেকে মাঝারি মানের প্লাস্টিসিটি প্রদর্শন করে। সংকোচনশীলতা পরীক্ষায় দেখা যায় যে, পরীক্ষিত নমুনাসমূহ সাধারণ থেকে অতি সংকোচনশীল বৈশিষ্ট্য সম্পন্ন। আয়তন সংকোচন গুনাংকের (m_v) মান অত্যন্ত কম যা ০.০৩১৭ m^2/MN থেকে ০.২৪১৪ m^2/MN এর মধ্যে অবস্থান করে এবং বিভিন্ন এলাকায় চাপ বৃদ্ধির সাথে সাথে পরিবর্তিত হয়। প্রাপ্ত m_v মান থেকে বলা যায় যে, পরীক্ষিত কর্দম মৃত্তিকা শক্ত থেকে প্লাস্টিক কর্দম শ্রেণির এবং মাঝারি থেকে স্বল্প সংকোচনশীল বৈশিষ্ট্য সম্পন্ন। সংকোচন সূচকের (C_C) মান ০.০০৫১ থেকে ০.৩৬৫৪ এবং ইহা চাপ বৃদ্ধির সাথে সাথে সমানুপাতিক হারে বৃদ্ধি পায় কিন্তু মৃত্তিকার শূন্যতা অনুপাত বৃদ্ধির সাথে সাথে হ্রাস পায়। প্রাপ্ত সংকোচন সূচকের মান হতে দেখা যায় যে, বিশ্লেষিত বরেন্দ্র কর্দম মৃত্তিকা নিম্ন থেকে মাঝারি সংকোচনশীল শ্রেণির অন্তর্ভূক্ত। এ পর্যবেক্ষণ m_v মানের সাথে সামঞ্জস্যপূর্ণ।

সামগ্রিক সংকোচনশীলতা বৈশিষ্ট্যসমূহ বিশেষ করে আয়তন সংকোচনশীলতা, সংকোচন সূচক এবং কনসিসটেনসি সীমার মান থেকে বলা যায় যে, পরীক্ষিত মৃত্তিকার নমুনাসমূহ নিম্ন থেকে মাঝারি প্লাস্টিসিটি সম্পন্ন এবং নিম্ন থেকে মাঝারি সংকোচনশীল কর্দম মৃত্তিকা। সুতরাং পরীক্ষিত বরেন্দ্র কর্দম মৃত্তিকার ভূ-প্রকৌশল বৈশিষ্ট্য খুব ভালো, যা অবকাঠামো নির্মানের জন্য অত্যন্ত উপযুক্ত।