Dish Method for Determination of Volumetric Shrinkage of Soils

Sagar Shrivastava[1], Sanjay Kumar Verma[2],

[1.] Gyan Ganga Institute of Technology and Science, Jabalpur, India
[2.] Takshshila Institute of Engineering and Technology, Jabalpur, India
`sagar.shrivastava@gmail.com, verma.sanjay090@gmail.com`

Abstract. Shrinkage characteristics of soils are very important soil parameters for design of safe and stable foundation. The volumetric shrinkage test gives a very effective idea about the shrinkage behaviour of the soils. Bureau of Indian Standards (BIS) recommended IS: 2720 (Part 6) – 1972 methods for the determination of shrinkage factors. This laboratory method is a very sophisticated and time taking method. Generally, this test is not easily available in the middle class and small towns, and everyone cannot afford the expense of this test. Authors developed an alternative method named the "Dish Method" to determine the volumetric shrinkage of soils. The study suggests a very simple, quick, effective, and economical procedure for determining of volumetric shrinkage of soils by Dish Methods. The proposed method provides a preliminary idea about the shrinkage characteristic of cohesive soil. In the present paper, the authors classified the soils and compared volumetric shrinkage by IS: 2720 (Part 6) – 1972 and Dish Method at ten different selected locations in Jabalpur town. Authors have also compiled the average degree of shrinkage of soil and classified it as very poor, poor, medium, or good soil.

Keywords: Volumetric Shrinkage, Bureau of Indian Standard (BIS), Dish Method, Shrinkage and Swelling.

1. Introduction

This paper is extension of a previous work of the authors and paper publishesd in, proceedings of the IGC-2019 Volume I Pages 73-81. In this paper authors have have conducted theirs studies at some more locations in Jabalpur. In the central India, the city Jabalpur (23^0 10' N, 79^0 57' E, MSL - 402 M) is seismically sensitive and located in an earthquake-prone area. As per IS: 1893-1984 (2002), Jabalpur comes under earthquake zone III [2]. This present study has been carried out in the city of Jabalpur and nearby locations. The study is specifically more applicable in cities like Jabalpur which are vulnerable to the occurrence of major earthquakes like the one which took place earlier. An earthquake of M 6.0 on the Richter scale occurred in Jabalpur in the early morning 4.22 hours on 22nd May 1997. The epicentre of the earthquake was located about 12 km SE of the city of Jabalpur [5]. The maximum intensity observed in the epicentre area due to this earthquake was VIII on the MMI scale. Maximum losses were observed on non-engineered constructions. Its after-effects were the death of about 50 people and a great loss of property exceeding rupee 500 crores [7]. Looking at the seismic vulnerability of the city, a study has been done to bring out the engineering characteristics of soils in some of the sensitive areas for safe and stable constructions. In this case study, 10 such sensitive locations have been selected, and field and laboratory tests e.g. Trial Pits, Trial Bores, Soil Colour, Moisture Content, Specific Gravity, Grain Size Analysis, Liquid Limit, Plastic limit, Shrinkage Factors, Free Swelling Index, etc. have been carried out to determine various parameters of the soil at an average footing depth level at selected locations [6]. The tests have been done as per Indian Standard methods recommended by the Bureau of Indian Standard (BIS). During the case study a method named - Dish Method, has been originated and developed by the authors. This method may be used as an alternative method for the determination of volumetric shrinkage of soils. Dish method may be considered a conventional method for the primary assessment of volumetric shrinkage; very easily, fast, and economically. Selected locations are listed in table 1 and also shown on the map of

Jabalpur city in figure 1.

Table 1. List of Selected Locations.

| S. No.	Selected Locations	Case Study Nos.	Longitude	Latitude
1	ISBT Madhotal, Jabalpur	CS 1	23^0 11' 31" N	79^0 54' 43" E
2	MR-4, Ukhri Road, Jabalpur	CS 2	23^0 10' 41" N	79^0 54' 40" E
3	Near Hotel Sukoon, South Narmada	CS 3	23^0 06' 17" N	79^0 52' 49" E
4	Near Hotel Krishna, Bhanwartal Park	CS 4	23^0 09' 51" N	79^0 56' 03" E
5	Sanjeevani Nagar,jabalpur	CS 5	23^0 10'13" N	79^0 53' 44" E
6	Near Garha Crossing, Jabalpur	CS 6	23^0 09' 56" N	79^0 54' 27" E
7	Bal Sagar, Bhedaghat Road	CS 7	23^0 09' 08" N	79^0 52' 55" E
8	Gwarighat, North Narmada	CS 8	23^0 06' 13" N	79^0 56' 40" E
9	VFJ Near, J.E.C. Jabalpur	CS 9	23^0 11' 39" N	79^0 59' 13" E
10	Adhartal Lake , Jabalpur	CS 10	23^0 12' 17" N	79^0 57' 08" E
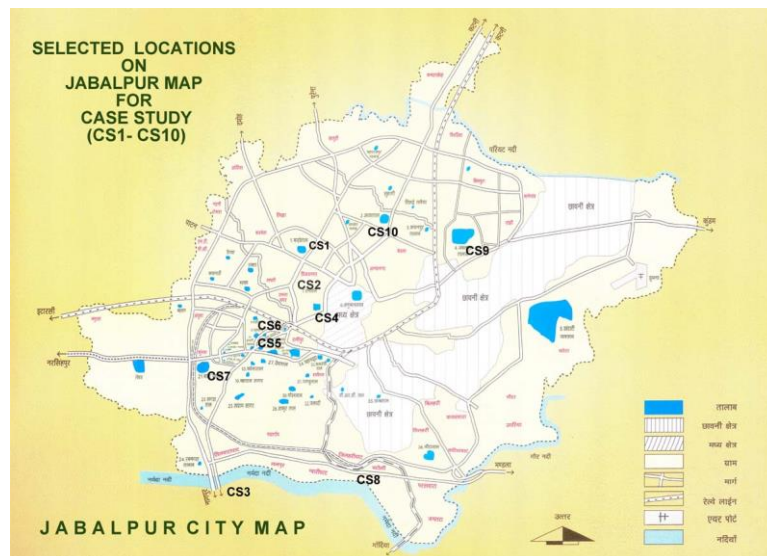
Fig.1. Selected Locations on Map of Jabalpur.
(Map Source: Jabalpur Ke Sarovar – Anmol Dharohar) [8]

2 Determination of Atterberg's Limits of Soil as per IS: 2720 (Part 5) and Classification of Soil as per IS: 1498 – 1970

The Classification of the soil have done as per IS: 1498 – 1970 and Atterberg's limits, e.g., Liquid Limit, Plastic Limit, and Plasticity Index of Soils are worked as per IS: 2720 (Part 5), for selected locations under study, are compiled in table 2.

Table 2. Soil Classification as per IS: 1498-1970 and Atterberg's Limits as per IS:2720 (Part 5).

S. No.	Case Study Nos.	Locations	Classification of Soils as per (ISC) IS: 1498 - 1970	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)
1	CS 1	ISBT Madhotal, Jabalpur	CH	57	25	35
2	CS 2	MR-4, Ukhri Road, Jabalpur	CH	58	27	31
3	CS 3	Near Hotel Sukoon, South Narmada	SML	32	27	5
4	CS 4	Near Hotel Krishna, Bhanwartal Park, Jabalpur	CI	42	27	15
5	CS 5	Sanjeevani Nagar, Jabalpur	CH	53	28	25
6	CS 6	Near Garha Crossing, Jabalpur	CH	55	24	31
7	CS 7	Bal Sagar, Bhedaghat Road, Jabalpur	CH	58	27	31
8	CS 8	Gwarighat, North Narmada, Jabalpur	SMI	39	29	10
9	CS 9	VFJ Near, J.E.C. Jabalpur	SMI	41	30	11
10	CS 10	Adhartal Lake, Jabalpur	CH	55	29	26

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3 Determination of Volumetric Shrinkage of Soil as per IS: 2720 (Part 6) - 1972

Shrinkage Factors e.g. Shrinkage Limit (%), Shrinkage Ratio, Volumetric Shrinkage (%) , and Degree of Shrinkage (%) at all selected locations in Jabalpur (CS1 – CS10) have been worked out as per the IS: 2720 (Part 6) [4]. Results of Shrinkage Factors are mentioned in table 3

Table 3. Shrinkage Factors at Selected Locations as per IS:2720 (Part 6).

S. No.	Case Study Nos.	Selected Locations	Shrinkage Limit (%)	Shrinkage Ratio	Volumetric Shrinkage (%)	Degree of Shrinkage (%)
1	CS 1	ISBT Madhotal, Jabalpur	12.76	1.95	69.75	41.09
2	CS 2	MR-4, Ukhri Road, Jabalpur	9.0	1.83	60.58	37.72
3	CS 3	Near Hotel Sukoon, South Narmada	15.83	1.79	31.52	23.96
4	CS 4	Near Hotel Krishna, Bhanwartal Park, Jabalpur	15.25	1.82	21.39	17.62
5	CS 5	Sanjeevani Nagar, Jabalpur	12.74	1.94	69.75	41.09
6	CS 6	Near Garha Crossing, Jabalpur	17.05	1.86	39.50	28.31
7	CS 7	Bal Sagar, Bhedaghat Road, Jabalpur	10.65	1.81	90.94	47.62
8	CS 8	Gwarighat, North Narmada, Jabalpur	14.54	1.73	37.89	24.42
9	CS 9	VFJ Near, J.E.C. Jabalpur	14.12	1.90	33.63	25.06
10	CS 10	Adhartal Lake, Jabalpur	16.55	1.73	35.39	26.14

4 Determination of Volumetric Shrinkage of Soil by Dish Method

The Dish method is developed by authors to determine the volumetric shrinkage of soils. This method can be considered a primary method to assess the shrinkage behaviour of soil. The proposed method suggests the test for the determination of volumetric shrinkage of soil very easily and economically. This test can be performed by the either one dish from three shrinkage dishes e.g. Steel dish, Plastic dish or Paper dish. As per this test; firstly determine the inner diameter and depth of these dishes by steel scale up to a least count 0.5 mm (Vernier caliper scale can also be used for more accuracy). Determine the volume of each type of dish. (In this case study, steel dish has been used and the diameter of the Steel dish is 5 cm and the depth of the dish is 2.5 cm). Take about 100 gm of dry soil sample and mix with water in an amount sufficient to fill the soil voids fully and to make the soil pasty enough to be readily worked into the dish without entrapping air bubbles [3]. Fill the dish with the prepared soil

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sample in three equal layers properly pressed with a spoon. On filling each one-third layer, the dish should be gently struck on the firm surface until the paste is thoroughly compacted and all entrapped air has been brought to the surface. After filling the dish in three layers, strike off the excess soil with a flat spoon. Put the dish for drying in the open air under sunlight for 24 to 48 hours. On drying the sample, measure the dimensions of the dried soil pat with a scale up to 0.5 mm. Finally, determine shrinkage in volume of the soil pat.

This method gives very appreciable results in comparison to laboratory test for determination of volumetric shrinkage as per Indian Standard IS: 2720 (Part 6). In this study volumetric shrinkage of soils for selected locations has been carried out with steel dish. Calculations for the determination of volumetric shrinkage of soils by steel dish method are shown in table 4 and pictures of the test procedure are shown in figure 2 (i) and (ii).

Table 4. Determination of Volumetric Shrinkage of Soils by Steel Dish Method.

S. No.	Case Study Nos.	Steel Dish			Wet Volume of Soil (V1)	Dry Pat			Dry Volume of Pat (V2)	Volumetric Shrinkage (%)
		Dia of Steel Dish	Depth of Steel Dish	Volume of Steel Dish		Dia of Dry Pat	Depth of Dry Pat	Volume of Dry Pat		
		CM	CM	CM^3	CM^3	CM	CM	CM^3	CM^3	{(V1 - V2)*100}/V2 (%)
1	CS1	5	2.5	49.06	49.06	4.3	2.05	29.76	29.76	64.88
2	CS2	5	2.5	49.06	49.06	4.7	1.8	31.21	31.21	57.18
3	CS3	5	2.5	49.06	49.06	4.75	2.2	38.97	38.97	25.91
4	CS4	5	2.5	49.06	49.06	4.75	2.4	42.51	42.51	15.41
5	CS5	5	2.5	49.06	49.06	4.5	1.9	30.20	30.20	62.43
6	CS6	5	2.5	49.06	49.06	4.65	2.2	37.34	37.34	31.38
7	CS7	5	2.5	49.06	49.06	4.35	1.8	26.74	26.74	83.49
8	CS8	5	2.5	49.06	49.06	4.75	2.1	37.19	37.19	31.90
9	CS9	5	2.5	49.06	49.06	4.65	2.25	38.19	38.19	28.46
10	CS10	5	2.5	49.06	49.06	4.7	2.15	37.28	37.28	31.59

2 (i)　　　　　　　　　**2 (ii)**

Fig.2. (i and ii). Dish Method for Determination of Volumetric Shrinkage (%) of Soils.

5　Comparison of Volumetric Shrinkage of Soils

During this study Volumetric Shrinkage of the soils at selected locations has been determined by dish method (developed by the author) and as per Indian Standard method IS: 2720 (Part 6) [4]. The difference in results of volumetric shrinkage by both the above-mentioned methods has also been determined. Comparisons of the results of both the methods for all ten selected locations are shown in Table 5.

Table 5. Comparison of Volumetric Shrinkage (%) between IS: 2720 (Part 6) and Dish Method [1].

S. No.	Name of Locations	Case Study Nos.	Volumetric Shrinkage as per IS: 2720 (Part 6) (%)	Volumetric Shrinkage by Dish Method (%)	Difference In Volumetric Shrinkage (%)
1	ISBT Madhotal, Jabalpur	CS 1	69.75	64.88	4.87 %
2	MR-4, Ukhri Road, Jabalpur	CS 2	60.58	57.18	3.4 %
3	Near Hotel Sukoon, South Narmada	CS 3	31.52	25.91	5.6 %
4	Near Hotel Krishna, Bhanwartal Park, Jabalpur	CS 4	21.39	15.41	5.98 %
5	Sanjeevani Nagar, Jabalpur	CS 5	69.75	62.43	7.32 %
6	Near Garha Crossing, Jabalpur	CS 6	39.5	31.38	8.12 %
7	Bal Sagar, Bhedaghat Road, Jabalpur	CS 7	90.94	83.49	7.45 %
8	Gwarighat, North Narmada, Jabalpur	CS 8	37.89	31.90	5.99 %
9	VFJ Near, J.E.C. Jabalpur	CS 9	33.63	28.46	5.15 %
10	Adhartal Lake, Jabalpur	CS 10	35.39	31.59	3.8 %

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6 Degree of Shrinkage of Soil

Degree of Shrinkage (Sr) is expressed as the ratio of the difference between initial volume and final volume of the soil sample to its initial volume Sr = (Vi-Vf)*100/Vi
As per the Schedig, the soil qualitatively based on its degree of shrinkage as shown in table 6

Table 6. Classification of the soil as per degree of shrinkage as per Dish Method

Degree of Shrinkage	Soil Quality
Sr <5%	Good Soil
Sr <5% to 10%	Medium Soil
Sr <10%- 15%	Poor Soil
Sr >15	Very Poor Soil

Case Study Nos.	Steel Dish			Wet Volume of Soil (V1)	Dry Pat				Dry Volume of Pat (V2)	Degree of Shrinkage of Soil	Quality of Soil
	Dia of Steel Dish	Depth of Steel Dish	Volume of Steel Dish		Dia of Dry Pat	Dia of Dry Pat	Depth of Dry Pat	Volume of Dry Pat			
	CM	CM	CM^3	CM^3	CM	CM	CM	CM^3	CM^3	DoS	QoS
CS1	5	2.5	49.06	49.06	4.3	4.3	2.05	29.76	29.76	39.35	Very Poor
CS2	5	2.5	49.06	49.06	4.7	4.7	1.8	31.21	31.21	36.38	Very Poor
CS3	5	2.5	49.06	49.06	4.75	4.75	2.2	38.97	38.97	20.58	Very Poor
CS4	5	2.5	49.06	49.06	4.75	4.75	2.4	42.51	42.51	13.36	Poor
CS5	5	2.5	49.06	49.06	4.5	4.5	1.9	30.20	30.20	38.44	Very Poor
CS6	5	2.5	49.06	49.06	4.65	4.65	2.2	37.34	37.34	23.88	Very Poor
CS7	5	2.5	49.06	49.06	4.35	4.35	1.8	26.74	26.74	45.50	Very Poor
CS8	5	2.5	49.06	49.06	4.75	4.75	2.1	37.19	37.19	24.19	Very Poor
CS9	5	2.5	49.06	49.06	4.65	4.65	2.25	38.19	38.19	22.16	Very Poor
CS10	5	2.5	49.06	49.06	4.7	4.7	2.15	37.28	37.28	24.01	Very Poor

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7   Results and Discussion

Volumetric Shrinkage of the soils at selected locations has been determined by Indian Standard Method and by Dish Method. The volumetric shrinkage of the soils determined by dish method is on average 4% to 8% less than that of the volumetric shrinkage determined by IS: 2720 (Part 6) [4]. **A c**omparison of the result is shown graphically in Fig 3.
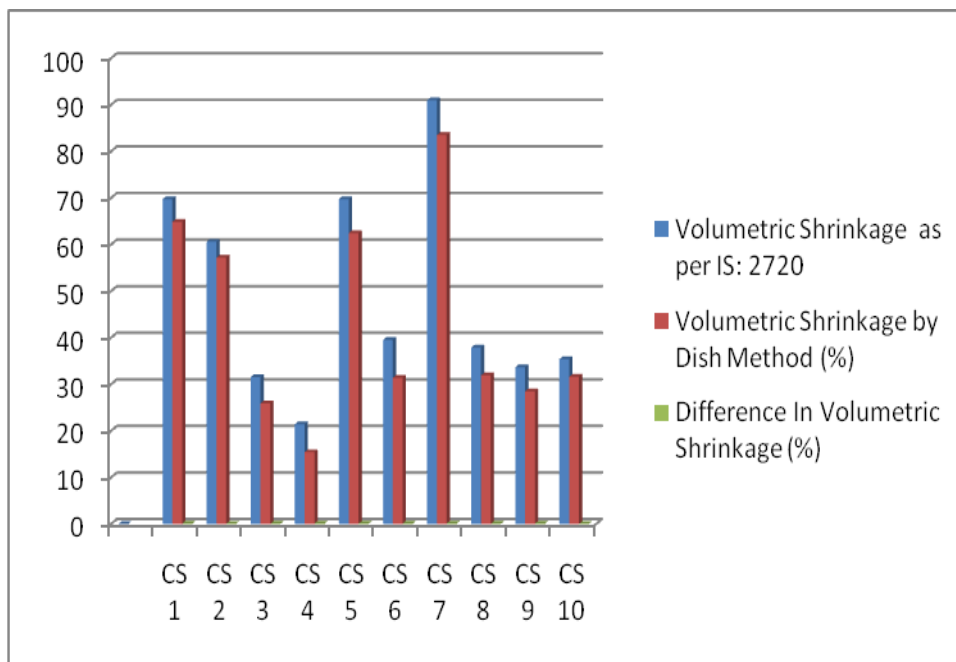

Fig. 3. Comparisons of Volumetric Shrinkage (%) by
IS: 2720 (Part - 6) Method and Dish Method.

8   Conclusions

Shrinkage on drying is indicative of the structure of the soil. The greater the shrinkage the more dispersed the structure. Volumetric shrinkage of soils at ten selected new locations in Jabalpur city and its surrounding has been assessed. Based on the methodology employed and the result obtained, it is quite appreciable that volumetric shrinkage of the cohesive soils determined by the dish method is very close to that of determined by laboratory methods as per IS: 2720 (Part 6) 1972. Dish method is very easy and economical. This method is so simple and can be used by common persons to assess the shrinkage behaviour of the cohesive soil, in small towns and villages where soil test facilities are commonly not available. By using Dish method the degree of soil can be determined in a very easy way and can assess quality of soil on ground as very poor, poor, medium or good soil. Dish Method is hereby proposed to prepare an I.S. code for determination of volumetric parameters of the soil.

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