EFFECT OF WATER-CLAY RATIO, CLAY CONTENT AND ADDITIVES ON THE MOULDABILITY AND COMPACTABILITY OF BENTONITE BONDED SANDS

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ABSTRACT

Experiments were carried out to study the effects of water/clay ratio, clay content and additives on the mouldability and compactability of bentonite bonded sand mixes. Results of the experiments indicate that for a given clay content (i) Mouldability gradually decreases with increase in water/clay ratio and the decrease is more significant in the water/clay ratio range of 0·3 to 0·7, (ii) Compactability increases with the increase in water/clay ratio of upto about 0·5 and remains essentially constant beyond a water/clay ratio of 0·5. (iii) At all water/clay ratios addition of dextrine decreases the mouldability and increases compactability whereas coal dust increases the mouldability and in creases compactability.

Key words. Water- lay ratio, Mouldability compactability, Bentonite bonded sands.

INTRODUCTION

Sand casting technique is the most widely used foundry process. Sand is a good refractory material, abundantly available and is quite cheap. Modern technology places increasing emphasis on the quality of the casting as well as the surface finish of the castings. The surface finish and the dimensional stability of the castings depend to a large extent on the properties of the moulding sand. Testing of sand, for its physical properties, is widely accepted as a method for the control of mould quality in the sand casting process.

Although several investigators have reported that the physical properties of the sand mixtures are known to affect the mould quality, it is reported that mouldability and compactability are the factors controlling the mould quality, and hence the casting quality. It is claimed that these two properties

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are enough to determine the conditions of the moulding sands and it is not necessary to determine the other physical properties at all [1–5]. However, at present, very little information is available on the effect of several variables on the mouldability and compactability of moulding sands and the interrelation between these two properties and with the other physical properties of the moulding sand mixtures.

Hence in this investigation experiments were carried out to study systematically the effect of moulding sand ingredients (sand, water and clay) and additives (dextrine and coal dust) on the mouldability, compactability and other physical properties of moulding sand mixtures. Also attempts were made to interrelate the various physical properties of the sand mixture, including the mouldability and compactability.

Previous Work

The various physical properties of moulding sand are influenced by several variables like the size, shape and distribution of the sand grains, the type and amount of the binder and the moisture content, the type and quantity of additives employed, mulling time and storage time, batch capacity and the method of addition.

It is reported that higher values of mouldability, compactability, strength and hardness are obtained with round sand grains [6–8]. Several investigators have observed that bentonite having high liquid limit (exceeding 500) and gelling index (exceeding 8·2) are suitable to obtain desirable physical properties [9–10]. The influence of moisture and selected additives on mouldability and compactability of moulding sand mixtures has been studied in great detail by several investigators. Results of some of the above investigators have shown that both mouldability and compactability are important in controlling the degree of temper (moisture content) of the moulding sand mix. Addition of one percent cereal to the production sand is found to increase the mouldability to a greater extent than does the addition of one percent cellulose [7]. Mulling time as also found to quickly change all the physical properties of the moulding sand mixture [11]. Over size batches reduce the efficiency of mixing and as a result the mouldability index increases with the increase in batch size.

Experimental Work

Materials used

Sand.—Sand obtained from Mangalore (South India) was used in the present investigation (details in Table I).

TABLE I

Sieve Analysis of Sand

B.S. Sieve No.	% Retained
8	..
16	..
22	0.4
30	0.8
44	2.6
60	19.5
100	58.5
150	17.2
200	0.7
Pan	0.3

AFS grain fineness No = 63·55

AFS clay content .. 0·45%
Colour of sand .. Milk white.

Clay.—Bentonite having a pH value of 8 and liquid limit of 520, swelling index of 146 percent and moisture content of 7·2 percent was used in this investigation.

Sand Preparation

The sand mixture was prepared in a batch type 5 kg capacity laboratory muller and the following procedure was adopted in the preparation of the sand mixture.

(*a*) *For sand mixture without additives* —To the weighed quantity of sand, calculated quantity of water was added and mulling was carried out for 2 min. The required quantity of clay was then added and mulling was continued for a further period of 4 min.

(*b*) *For sand mixture with additives*.—To the sand required quantity of additive was added and the mixture was mulled for 1 min. Water was then added and mulling was continued for 2 min. Finally the required quantity of clay was added and mulling was continued for a further period of 3 min. The mulled sand was stored in a polythene container and proper care was taken to avoid the loss of moisture by evaporation during storage.

Variables Studied

The variables studied, were the clay content, water-clay ratio and additive content.

Tests Conducted

Following were the tests carried out

1. Mouldability
2. Compactability
3. Green Compression Strength
4. Green Shear Strength and
5. Green Hardness.

Mouldability measurement

For the determination of mouldability a mouldability tester (Hoto-graph in Fig. 1) was fabricated as per the details, given by Dietert, Graham and Hanna [1, 2, 12]. In this test, a 200 gm sample of sand mixture (riddled through a 3/8 inch sieve) was placed in a 7 inch diameter cylindrical rotary

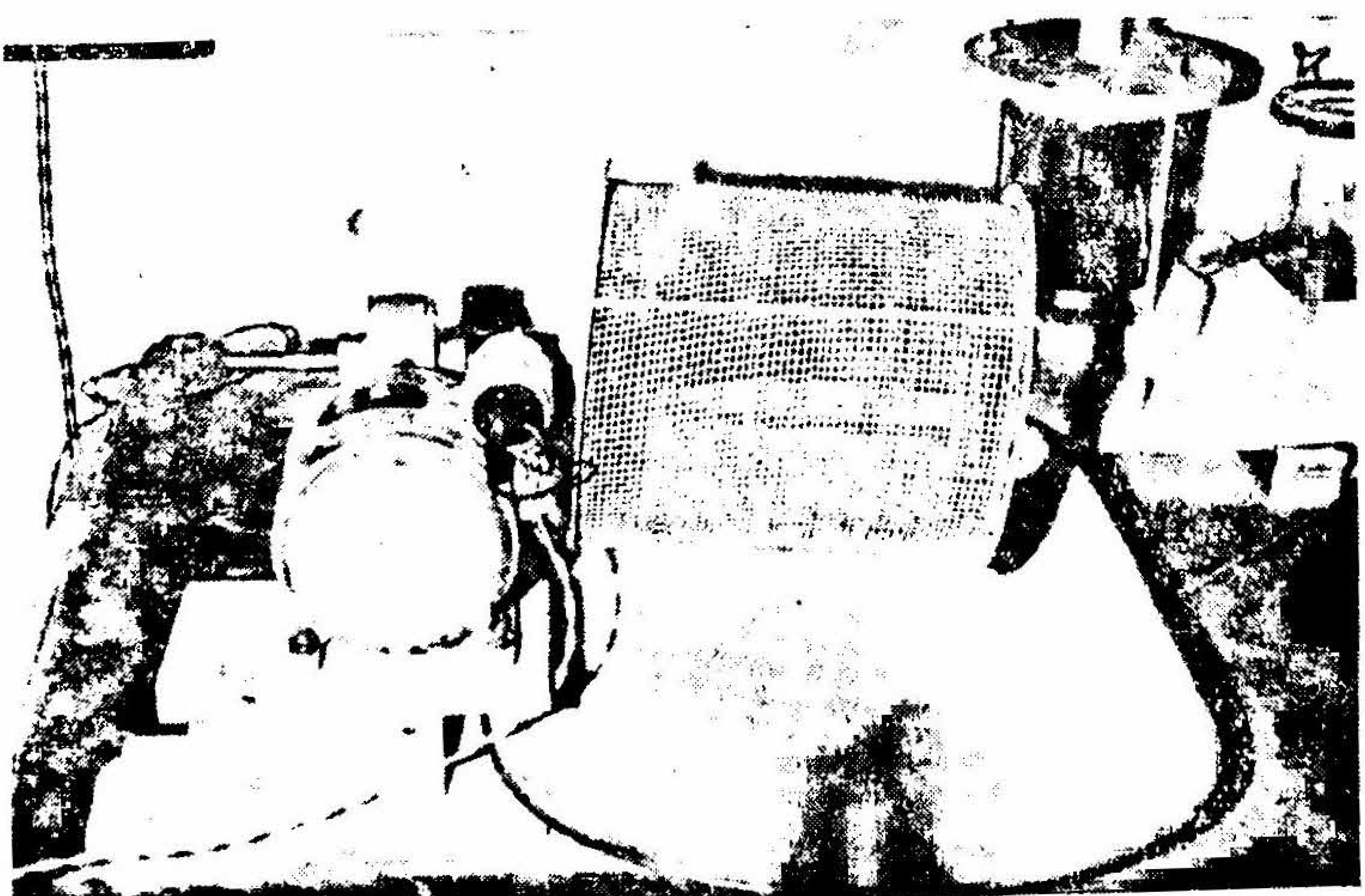

FIG. 1. Mouldability tester.

screen (8 mesh) which was supported at an angle of 7 degrees to the horizontal and rotated by a 57 rpm motor for a pericd of 10 sec. The weight in grams of the sand passing through the screen during this interval divided by two was recorded as the mouldability index.

Compactability measurement

Compactability of the moulding sand mixture was deteimined using the standard GF method. The standard GF compactability tube was filled with the riddled sand, the sand was compacted at a pressure 200 kp and the compactability was directly read as a percentage. In Fig. 2 is shown the photograph of the GF compactability tester employed.

FIG. 2. G. F. Compactability tester.

Green Compression and Green Shear Strength

Green compression and green shear strength were measured according to the standard test procedures using the universal sand testing equipment.

Green Hardness

Green hardness was measured by a Dietert's mould hardness (B scale) tester.

Test Results and Discussions

The values of the compactability and mouldability at different clay content and water-clay ratios with and without additives are given in Fig. 3.

Mouldability

Effect of water-clay ratio and the clay content.—In Fig. 3 is shown the plots of mouldability index *versus* water-clay ratio for different clay contents. A study of these plots shows that:

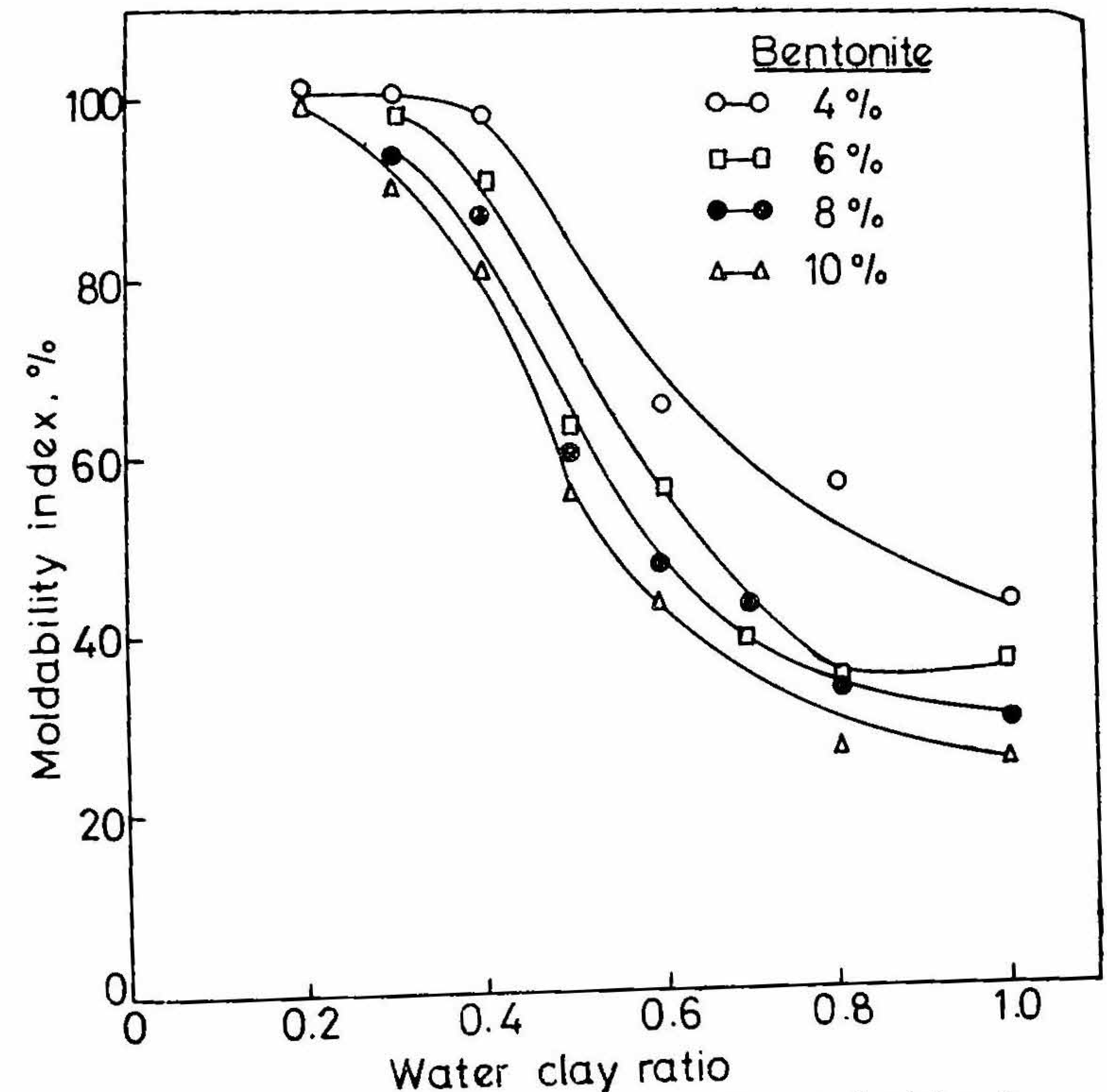

FIG. 3. Effect of water-clay ratio on mouldability of bentonite bonded sands.

(*a*) For a given water-clay ratio, an increase in the clay content decreases the mouldability index.

(*b*) For a given clay content, increase in the water-clay ratio decreases the mouldability index.

(*c*) The decrease in the mouldability index with the increase in water-clay ratio at a given clay content is gradual upto a water-clay ratio of about 0·3, followed by a rapid drop in the mouldability index upto a water-clay ratio of about 0·8, and beyond this water-clay ratio, the change in the mouldability index is not appreciable. (However, in the case of 4% clay content sand, this trend is not fully valid).

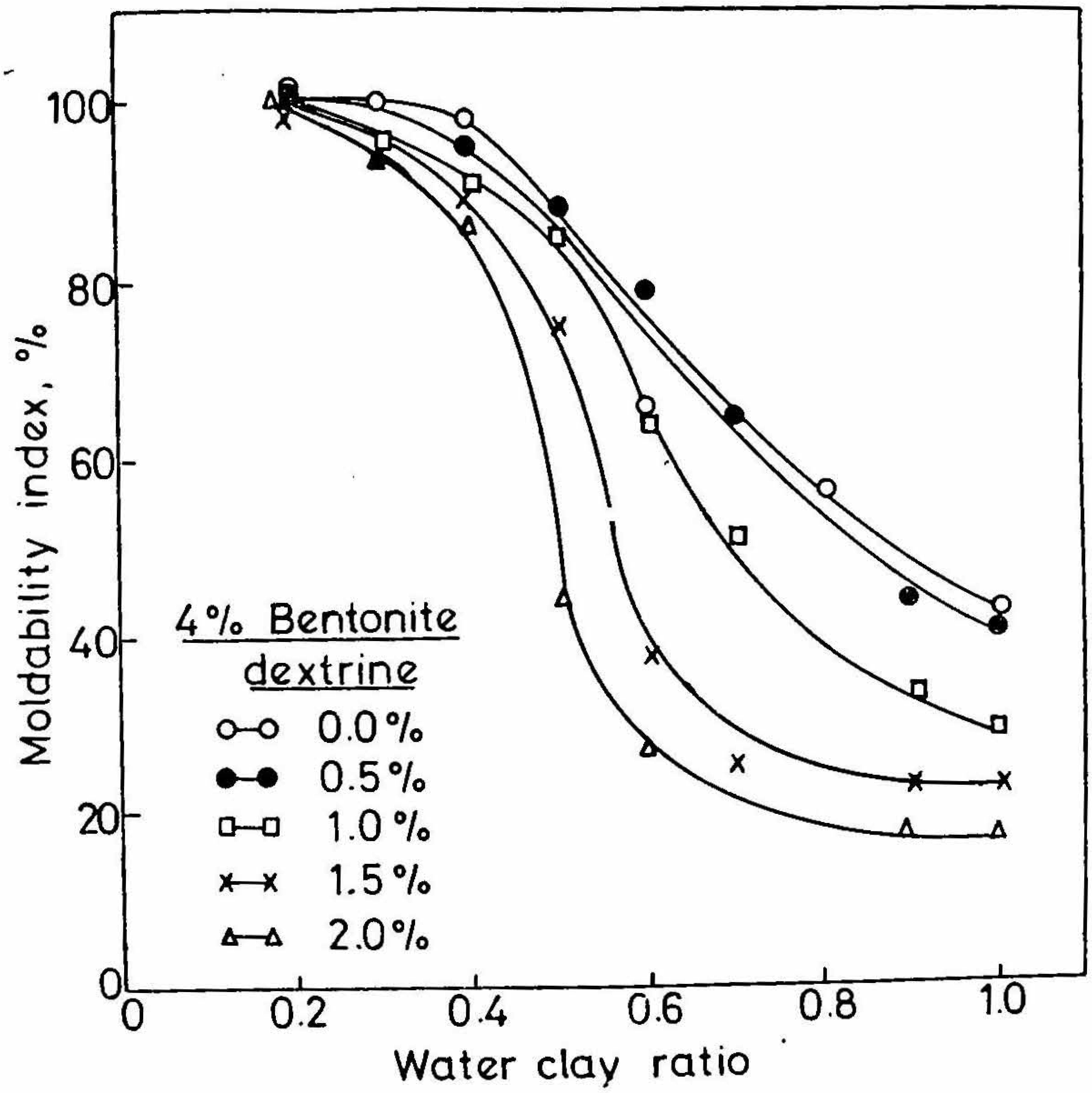

FIG. 4. Effect of dextrine on mouldability of 4% clay sands.

Effect of Additives

A. *Dextrine*

A careful study of the plots relating mouldability index and water-clay ratio for various dextrine contents (typical plots given in Figs 4 and 5) reveals that:

(*a*) For a given clay content addition of dextrine decreases the mouldability index for all the water-clay ratios investigated.

(*b*) The decrease in the mouldability index with the increase in the water-clay ratio in the lower ranges of water-clay ratio is much more significant for the sands with dextrine contents than for the sands without dextrine. This is true for all the percentages of bentonite content.

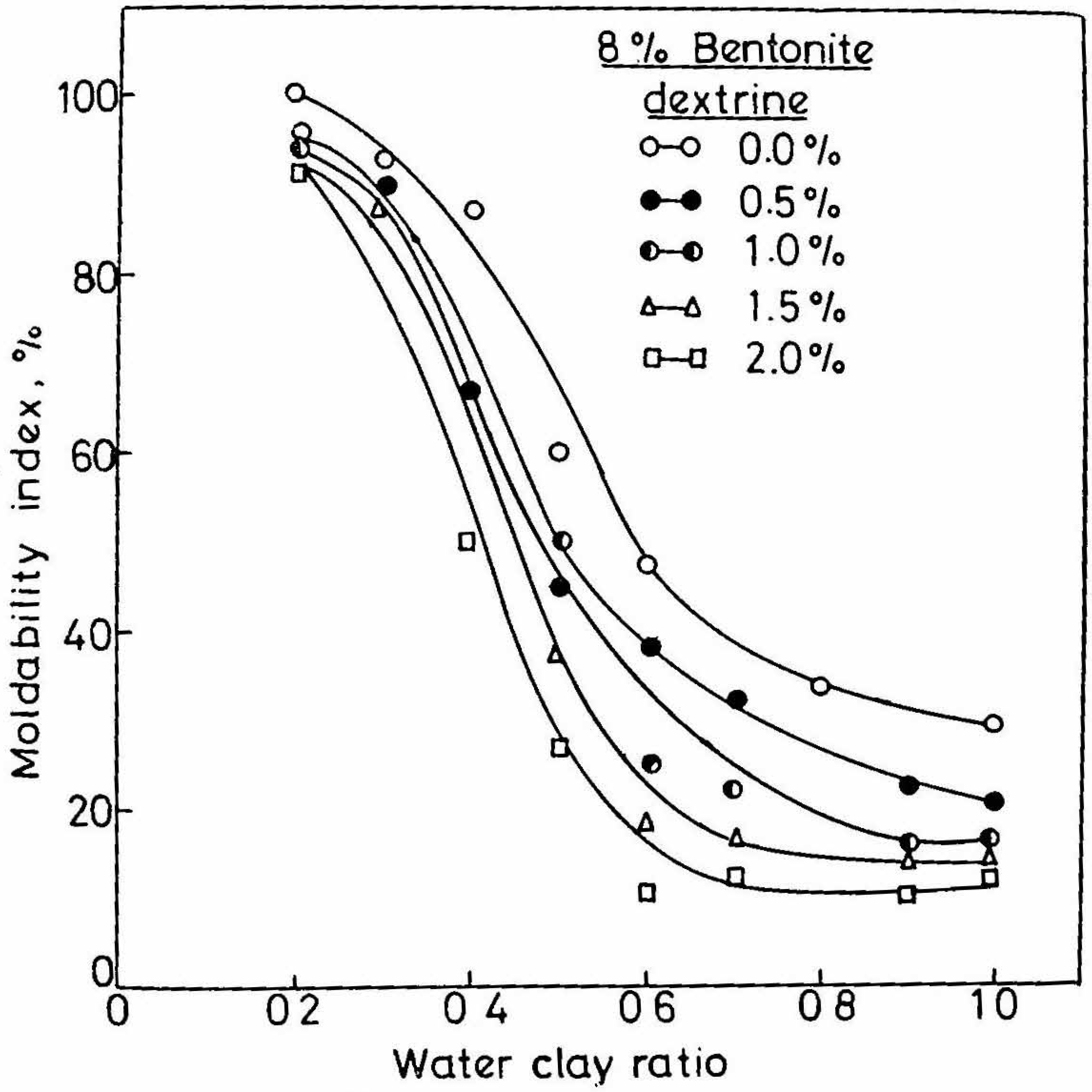

FIG. 5. Effect of dextrine on mouldability of 8% clay sands.

(*c*) In the case of 4% bentonite content sands, the change in the mouldability index with the increase in water-clay ratio, in the higher ranges of water-clay ratios is insignificant at higher dextrine content sands than lower dextrine content sands.

However, when the bentonite content is higher than 4%, irrespective of dextrine content, the change in the mouldability index with the change in the water-clay ratio is negligible at higher water-clay ratios (approximately beyond 0·7%). The above variations are mainly due to the water absorbing ability and strong swelling action of dextrine. The decrease in the mouldability index with the dextrine addition is due to the fact that dextrine improves the plasticity of the sand mix.

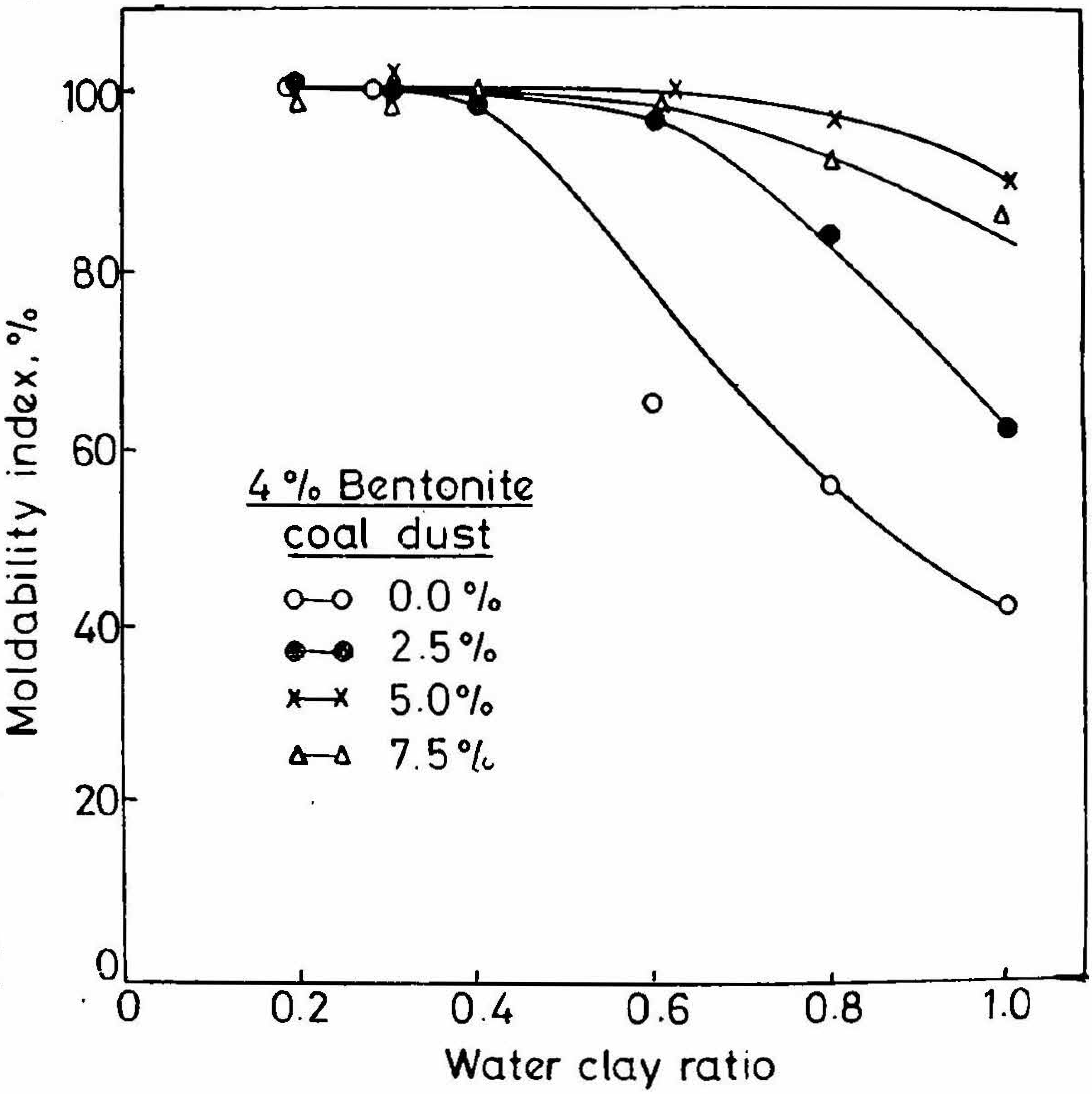

FIG. 6. Effect of coal dust on mouldability of 4% clay bonded sands.

B. *Coal Dust*

A study of the plot indicating the effect of coal dust on mouldability index (typical plots given in Figs. 6 and 7) indicates that:

(*a*) Addition of coal dust increases the mouldability index for all the clay-contents and the water-clay ratios investigated.

(*b*) As in the case of sands without any additives, in this case also, the change in mouldability index with the increase in the water-clay ratio is negligible in the lower range of water-clay ratios. However, with the addition of coal dust, the range of water-clay ratio in which the change in

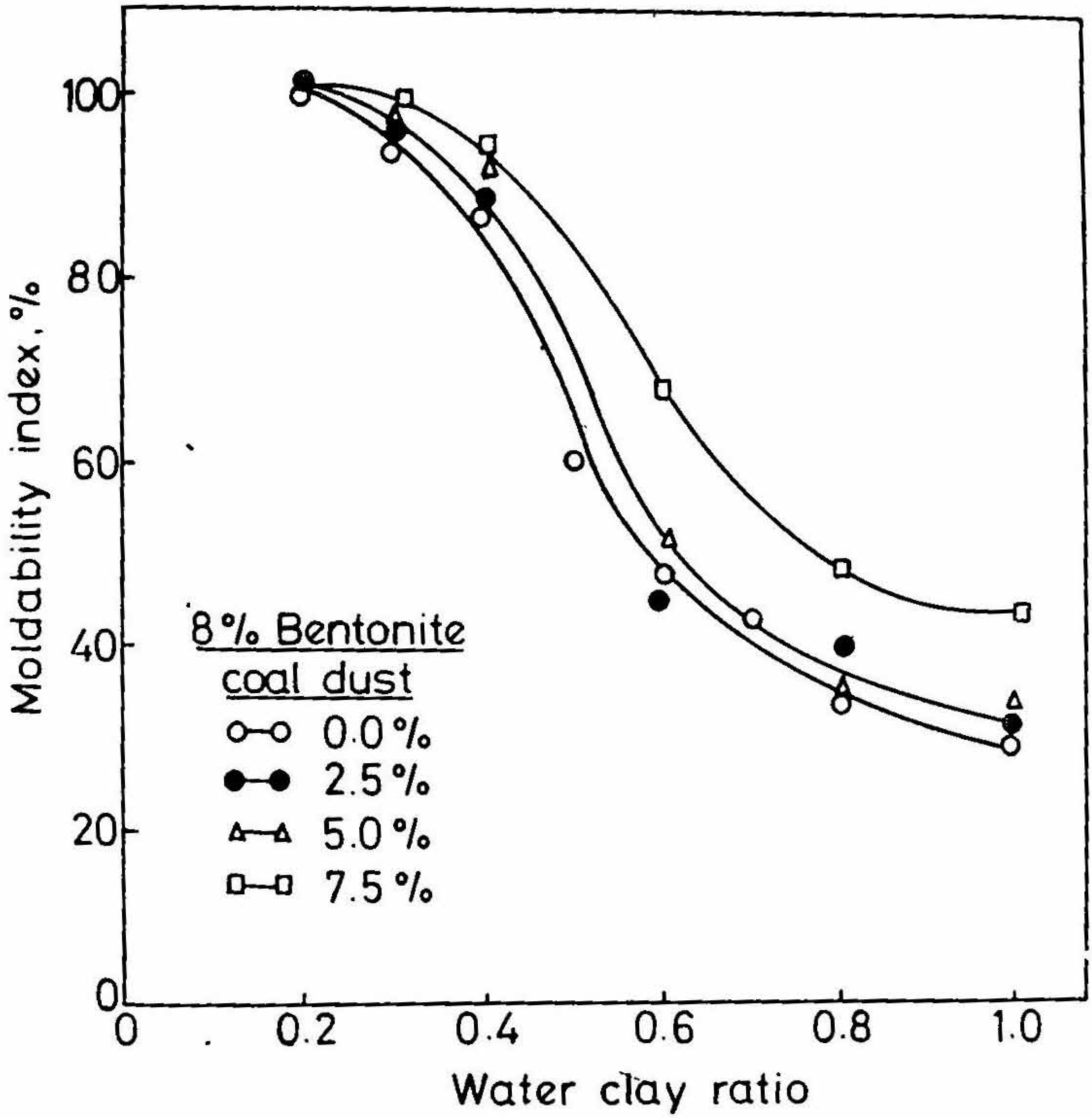

FIG. 7. Effect of coal dust on mouldability of 8% bonded clay sands.

mouldability is negligible is extended to higher values. This effect increases with the increase in the coal dust content.

(*c*) The effect of addition of coal dust in extending the range in which mouldability is insensitive to variations in water-clay ratio, to a higher value of water-clay ratio is significant for 4% bentonite sands, somewhat less for 6% bentonite sands and negligible for 8% bentonite sands.

Compactability

Effect of water-clay ratio and clay content.—In Fig. 8 is shown the curves of compactability *versus* water-clay ratio for different clay contents. A study of these plots indicates that:

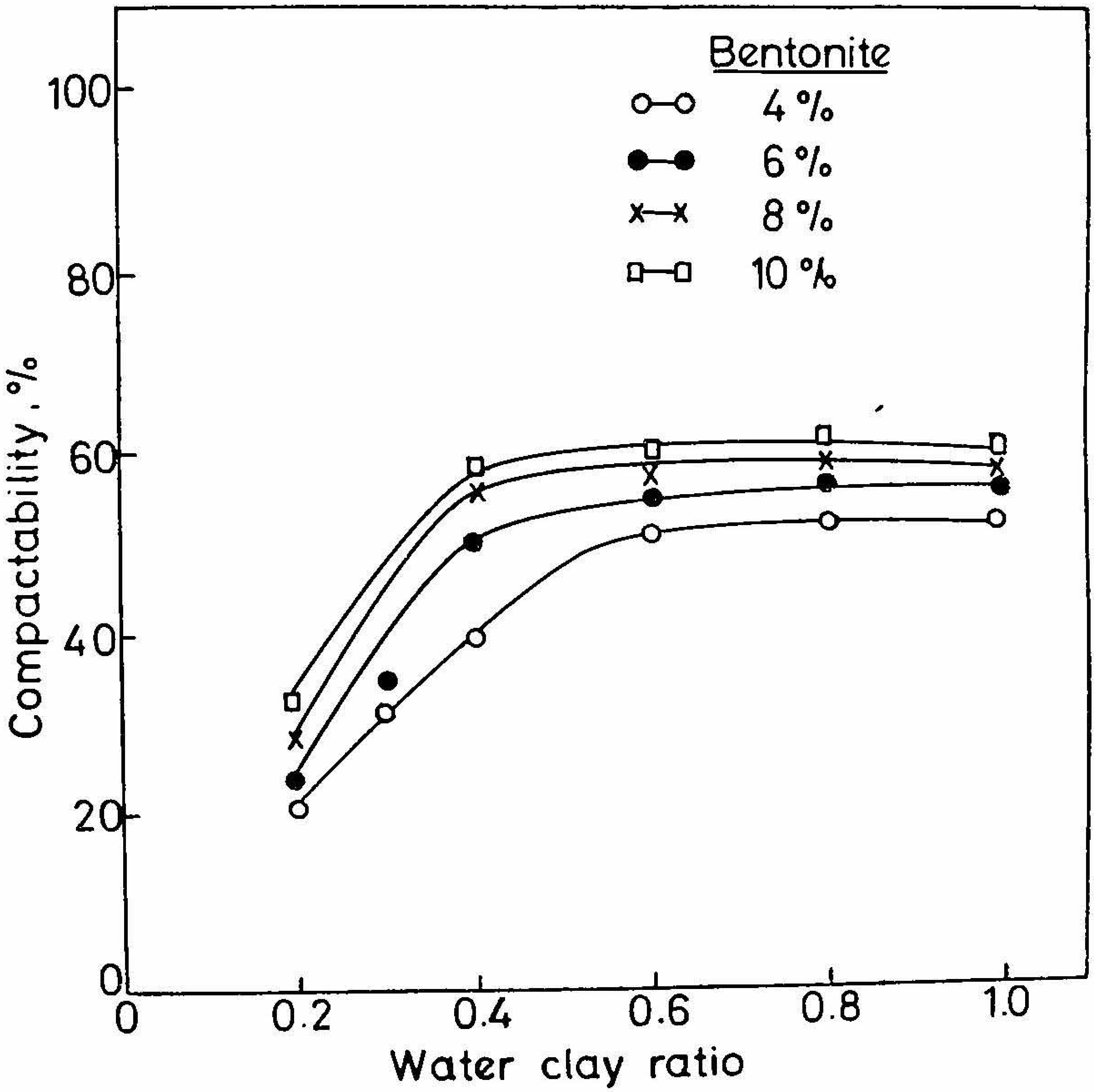

FIG. 8. Effect of water-clay ratio on compactability of bentonite bonded sands.

(*a*) At any clay content, compactability increases rapidly upto a water-clay ratio of about 0·6 and then remains essentially constant with further increase in the water-clay ratio.

(*b*) For a given water-clay ratio, an increase in the clay content increases the compactability.

Effect of Additives

A. *Dextrine*

A study of the plots demonstrating the effect of dextrine on compactability (typical plots given in Figs. 9 and 10) shows that:

(*a*) As in the case of straight sands, in the case of sands with dextrine addition also, compactability increases with the increase in the water-clay ratio.

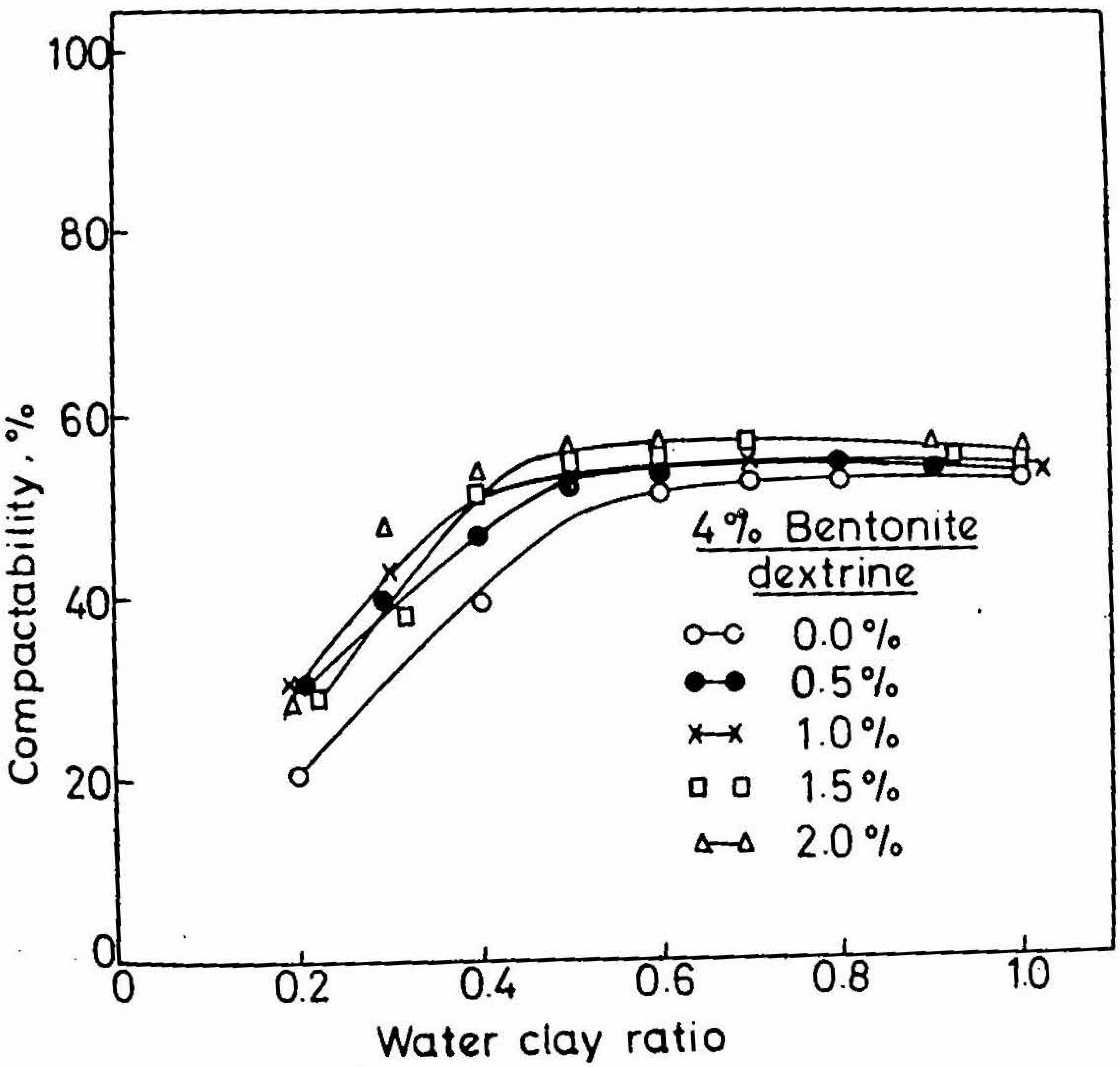

FIG. 9. Effect of dextrine on compactability of 4% clay sands.

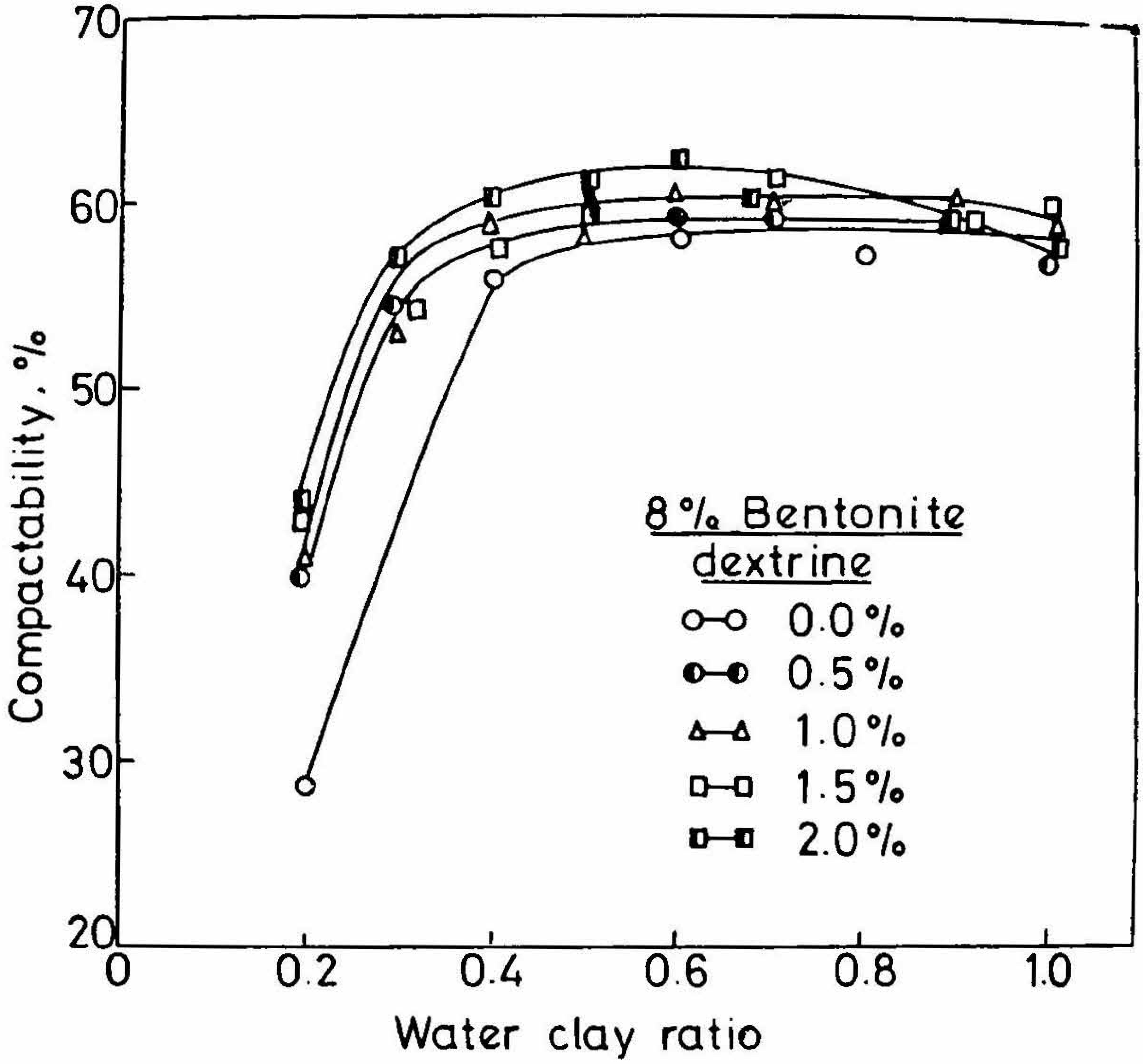

FIG. 10. Effect of dextrine on compactability of 8% clay sands.

(*b*) Compactability remains essentially constant beyond a water-clay ratio of about 0·55 for straight sands and 4% bentonite sands, whereas for 6% and 8% bentonite sands compactability remains more or less constant beyond water-clay ratio of 0·5 and 0·4 respectively.

(*c*) For a given clay content and water-clay ratio, increase in the dextrine content increases the compactability.

B. *Coal Dust*

A study of the plots relating the compactability and water-clay ratio for various coal dust contents (typical plots given in Figs. 11 and 12) indicates that:

(*a*) While without coal dust addition, compactability is constant for water-clay ratio beyond 0·55 at all clay contents, with the addition of coal dust compactability remains unchanged only beyond a water-clay ratio of about 0·65.

(*b*) For a given water-clay ratio and a clay content, addition of coal dust decreases the compactability.

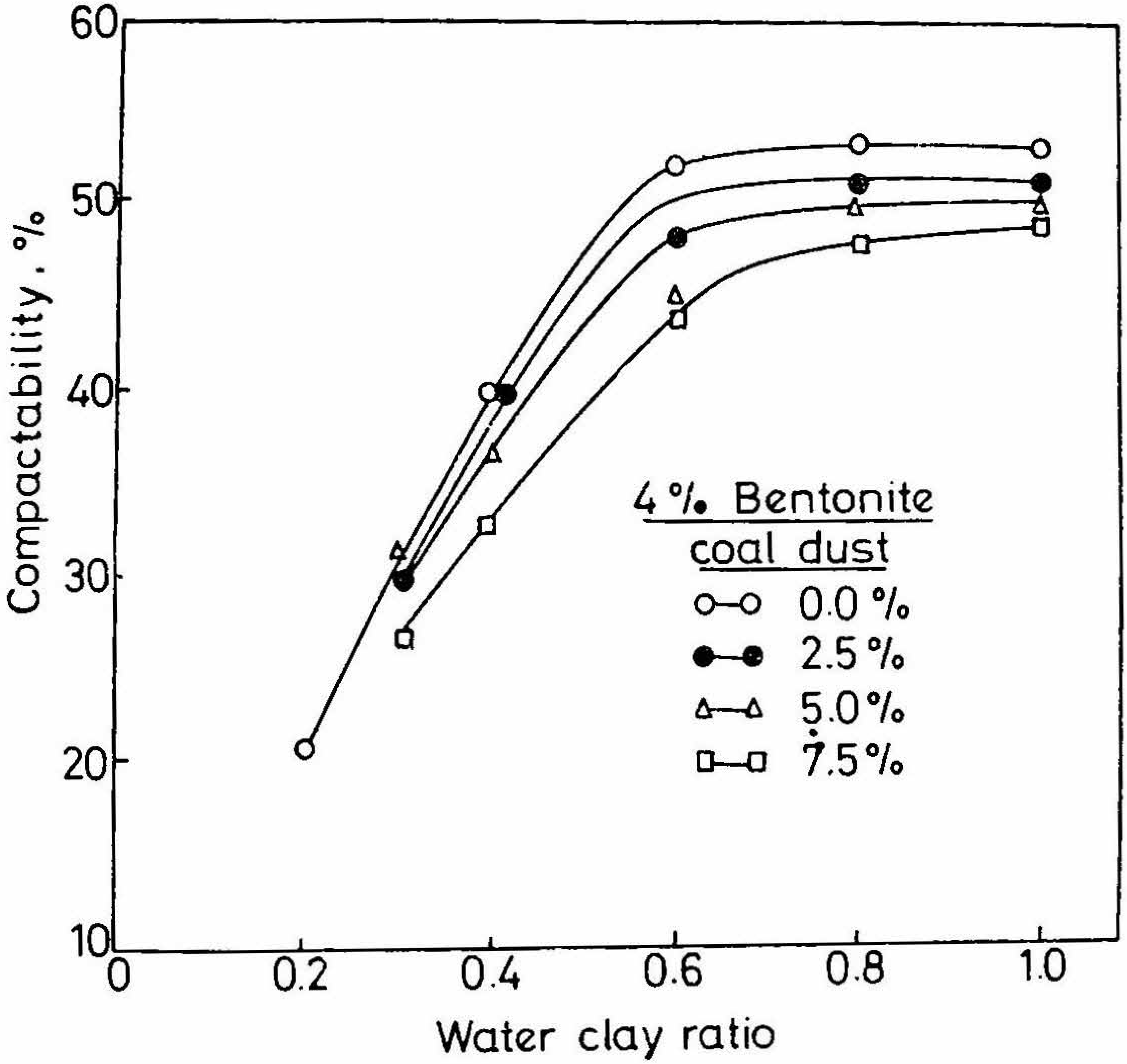

FIG. 11. Effect of coal dust on compactability of 4% clay bonded sands.

Relation between Mouldability and Compactability

A. *For Straight Sands*

The relation between the mouldability index and compactability for straight sands is indicated in Fig. 13. From the figure it can be seen that the mouldability index is appreciably constant upto a compactability value of 30%, followed by a gradual change in the mouldability index upto 50% compactability, and a steep fall in the mouldability index in the range of

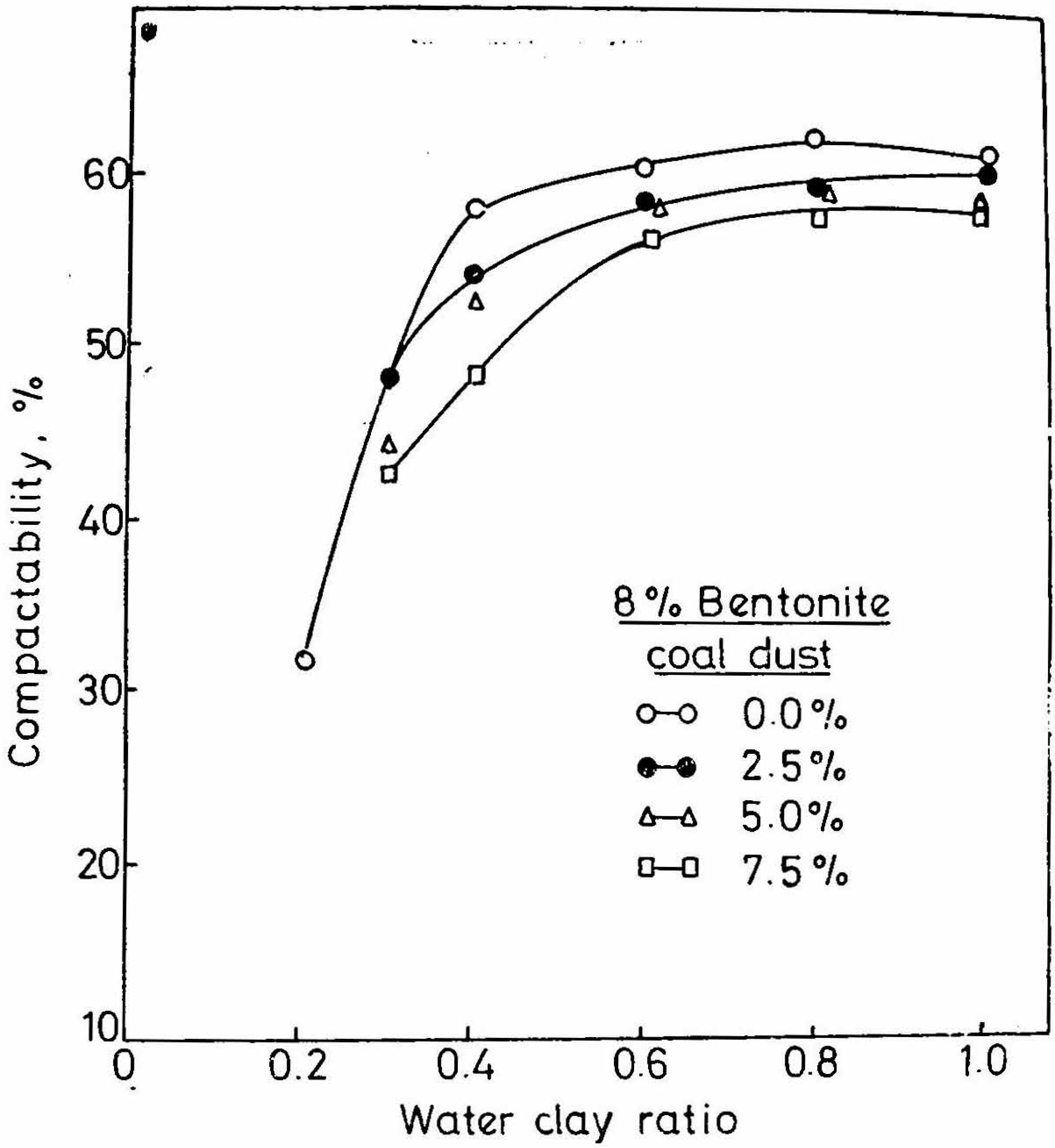

FIG. 12. Effect of coal dust on compactability of 8% bentonite bonded sands.

50 to 60% compactability. It is also apparent from the graph that only a portion of the whole curve is useful (mouldability of 90–60 and a compactability of 45–50) because above a mouldability index of 90, there is large variation in compactability with approximately constant mouldability index and there is a large variation in the mouldability index at constant compactability of about 60%.

B. *With Dextrine Addition*

The relation between the mouldability index and compactability for sands containing dextrine is indicated in Fig. 14 which shows that the

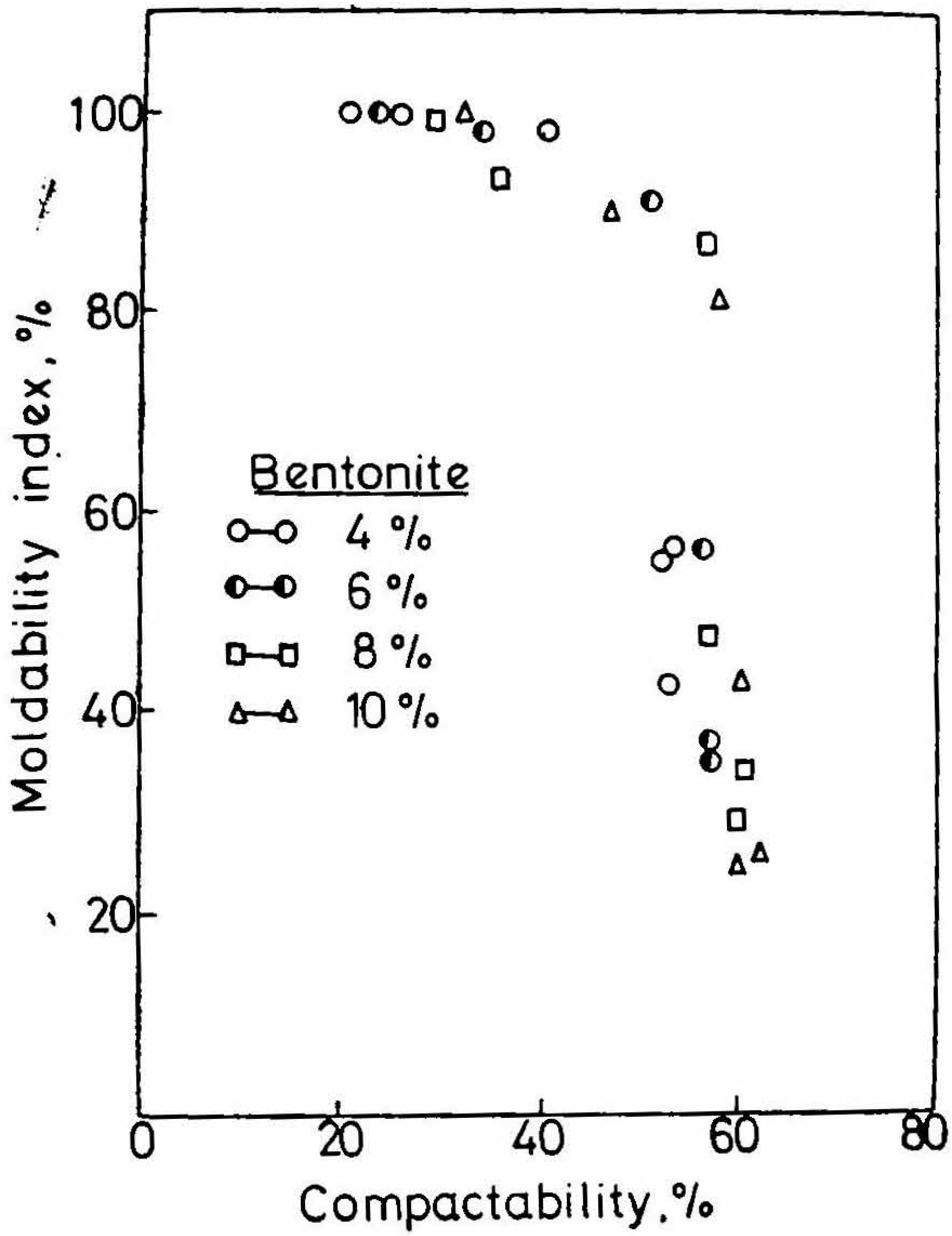

FIG. 13. Interrelation between mouldability and compactability of bentonite bonded sands.

mouldability index gradually falls upto a compactability value of about 50% and subsequently mouldability index falls very steeply with only a little change in compactability.

C. *Coal Dust Addition*

As indicated in Fig. 15 the mouldability index remains constant upto a compactability value of about 45%, followed by a gradual drop in mouldability index upto 52% compactability beyond which there is a steep fall in the mouldability index with slight increase in compactability. The

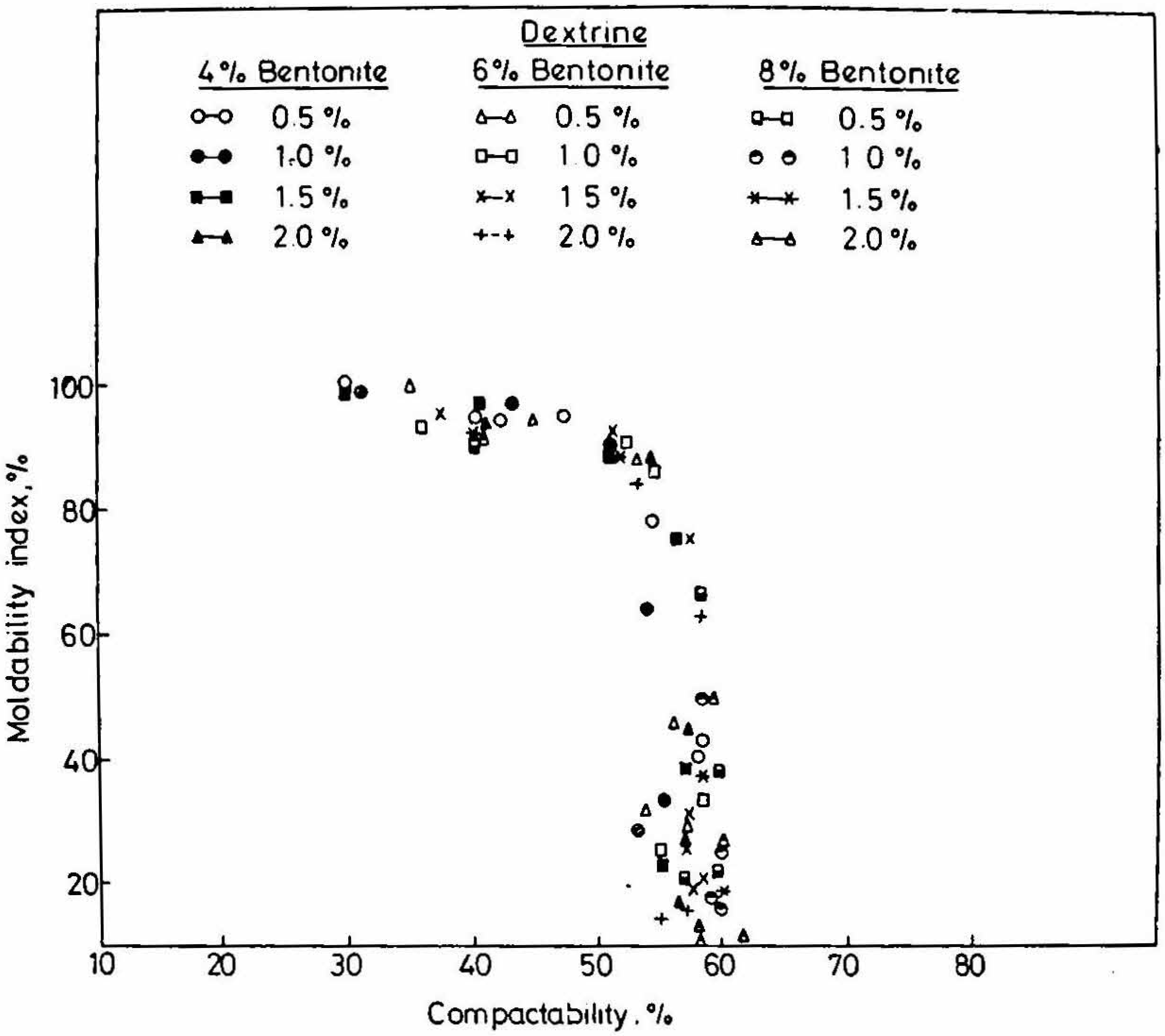

FIG. 14. Interrelation between mouldability and compactability with dextrine as additive.

range in which the sands can be operated is limited as compared to straight sands.

Relation between Mouldability and Green Compression Strength

The relationship between mouldability index and the green compression strength for sands containing dextrine additions for different bentonite contents is indicated in Fig. 16 which indicates that:

(*a*) At a given clay content with the increase in mouldability index, green compression strength gradually increases, (the rate of increase increases with the increase in mouldability index) reaches a peak value and thereafter, decreases with further increase in the mouldability index.

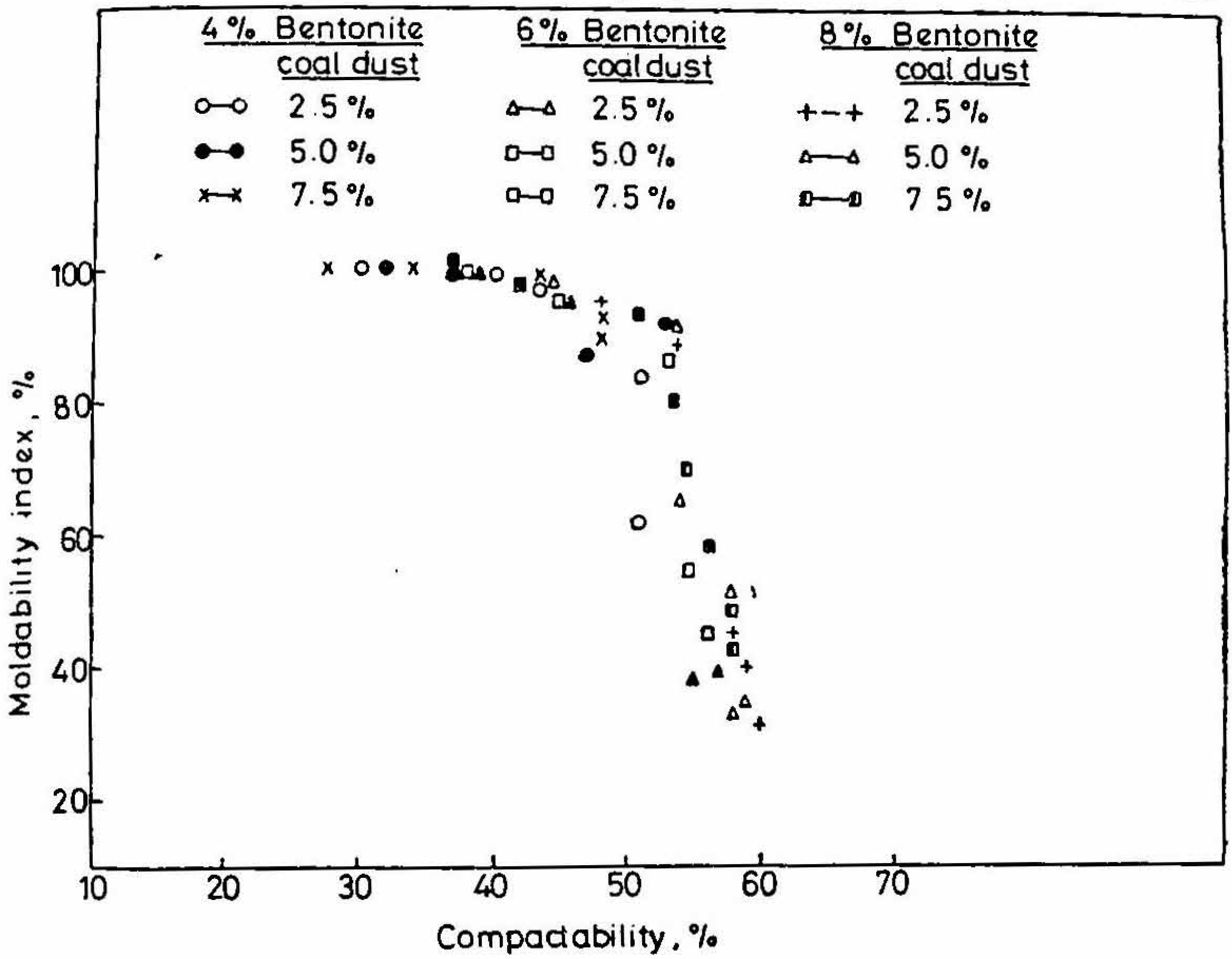

FIG. 15. Interrelation between mouldability and compactability with coal dust as an additive.

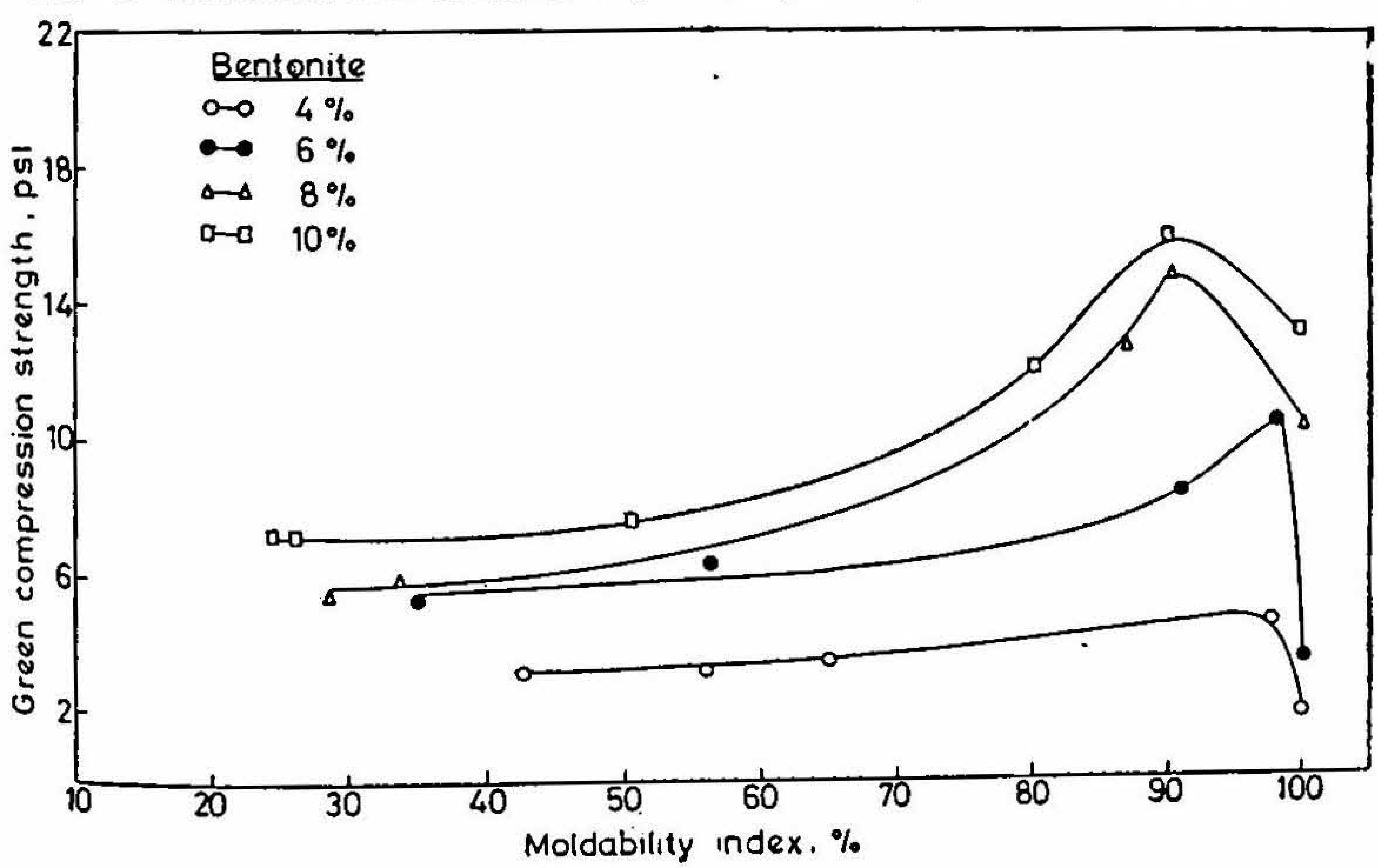

FIG. 16. Interrelation between green compression strength and mouldability.

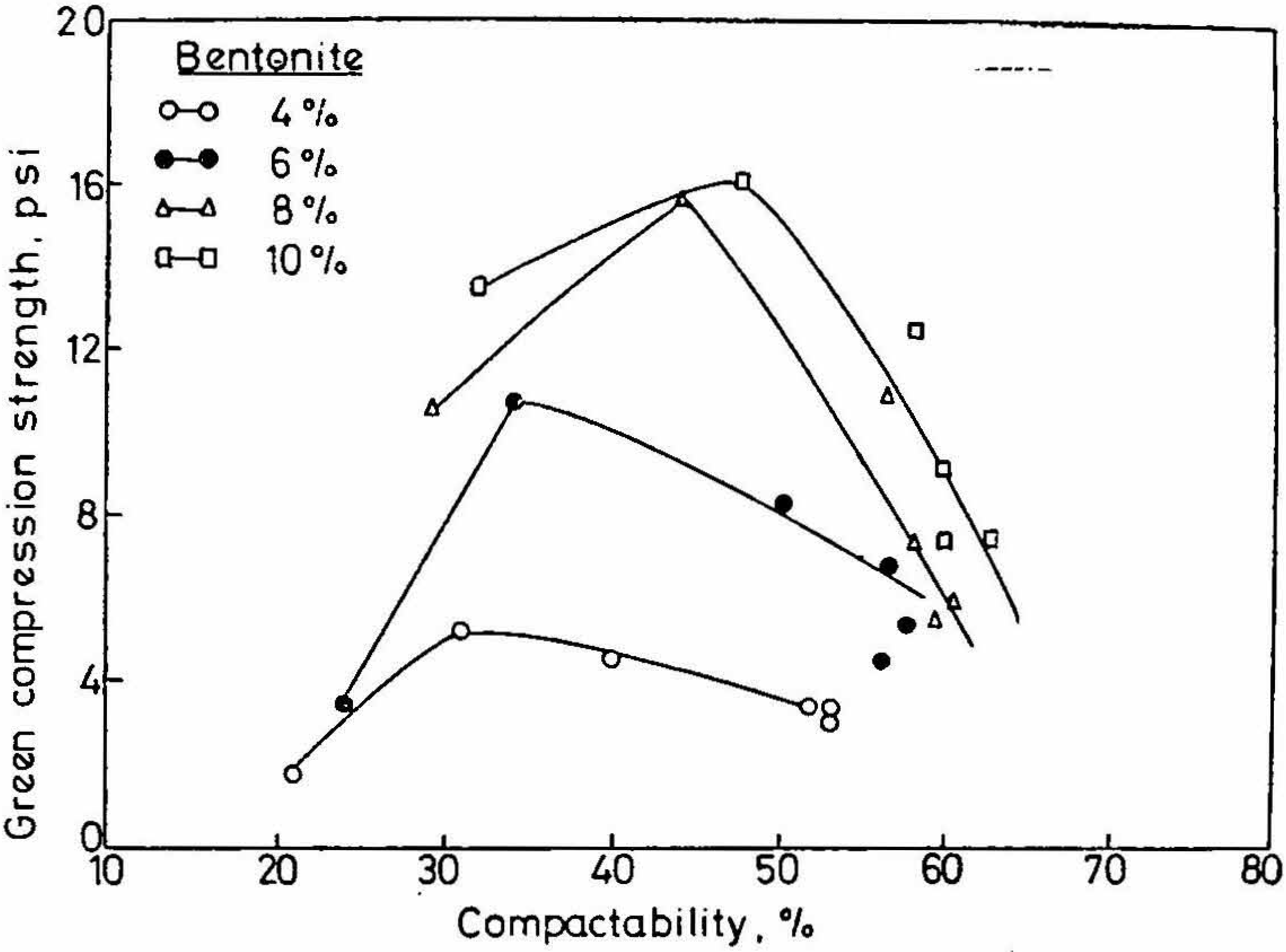

FIG. 17. Interrelation between green compression strength and compactability.

(*b*) For a given mouldability index, an increase in clay content increases the green compression strength.

(*c*) The mouldability index at which peak green compression strengths are attained, decreases with the increase in the clay content.

(*d*) Mouldability index in the range of 60 to 90 appears to be good both from the point of view of strength and mouldability.

Relation between Compactability and Green Compression Strength

Figure 17 gives the relationship between the compactability and green compression strength for different clay contents. A study of this indicates that:

(*a*) The green compression strength increases with increase in compactability, reaches a peak value and subsequently decreases.

(*b*) For a given compactability, an increase in clay content increases the green compression strength.

(*c*) The value of compactability at which green compression strength reaches a peak value increases with the increase in the bentonite content.

Green Compression Strength, Green Shear Strength and Green Hardness

The results of the experiments on the effect of water-clay ratio on the green compression strength, green shear strength and green hardness have shown that:

(*a*) For straight sands with a particular clay content, all the three values, namely, green compression strength, green shear strength and green hardness increase with increase in water-clay ratio, reach a maximum at a water-clay ratio of about 0·3 and they decrease with further increase in water-clay ratio.

(*b*) At a given water-clay ratio, increase in the clay content increases green compression, and green shear strength as well as green hardness.

(*c*) Addition of dextrine increases the compression strength of 4% clay sands at all water-clay ratios (the increase is maximum at 0·2 water-clay ratio) whereas for 6% clay bonded sands, the increase is appreciable only at 0·2 water-clay ratio and at all other water-clay ratios, the strength is lower than the straight sands.

(*d*) Coal dust increases the strength at all water-clay ratios and for all clay contents. The peak value, however, is shifted to 0·4 water-clay ratio as against 0·3 for straight sands.

(*e*) Both the additives tested increase the green shear strength at all water-clay ratios and clay percentages examined and this effect increases with the increasing percentages of the additives.

There is a gradual drop in green shear strength when water-clay ratio is increased from a low value to a high value, in the case of sands with dextrine additions. However, with coal dust as the additive, the strength attains a peak at a water-clny ratio of 0·4.

CONCLUSIONS

The results of the experiments on the effect of water-clay ratio on the mouldability, compactability and other physical properties of bentonite bonded sands with and without additives have indicated that:

(*a*) Green compression strength, green shear strength and green hardness increase gradually with increase in water-clay ratio, attain a peak at 0·3 water-clay ratio and on further increasing the water-clay ratio, they decrease.

(*b*) Mouldability gradually decreases with increase in water-clay ratio and in general the decrease is more significant in the water-clay ratio range of 0·3 to 0·7.

(*c*) Compactability in general increases with the increase in water-clay ratio of upto about 0·5 and remains essentially constant thereafter.

(*d*) In the case of straight sands and the sands containing dextrine as the additives, the desirable mouldability index of about 80% and compactability of about 45% are obtained at a water-clay ratio of about 0·45.

However, in the case of sands with coal dust as the additive, these desirable values of mouldability and compactability are obtained at much higher water-clay ratio depending on the bentonite and the coal dust content.

(*e*) At a compactability of about 55% the mouldability index can vary from a high value of about 80 to a low value of about 10.

(*f*) Irrespective of clay percentages and water-clay ratio, dextrine decreases the mouldability and increases compactability whereas coal dust increases the mouldability and decreases compactability.

(*g*) Green compression strength increases gradually with the increase in the mouldability index, reaches a peak and then decreases with further increase in the mouldability index.

(*h*) Green compression strength increases with the increase compactability, reaches a peak, and subsequently decreases.

The value of compactability at which peak green compression strength is reached increases with the increase in the clay content.

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