

Chapter Nine

BONDING CLAYS

The results of investigations on the bonding characteristics of a few bentonite samples collected from different locations in the country are presented in this chapter.

Rajasthan Bentonite

The sample of bentonite was supplied by *Messrs Tata Locomotive & Engineering Co. Ltd*, Tatanagar. It was in the form of lumps of 2–3 in. diam., pale yellowish in colour and contained 7.5 per cent moisture. It was crushed first in a jaw crusher and then in a hammer mill. The – 10 mesh product from the hammer mill was finely ground in a pulverizer. Bulk of the powdered product passed through 200 mesh sieve and was taken up for investigation.

The chemical composition of the bentonite is shown in Table 126.

The pulverized product had a specific gravity of 2.428 and showed fairly high swelling characteristics, the swelling index being 5.56. Suspensions of 1.5 g. of the bentonite in 100 ml. distilled water were distinctly alkaline. The pH value of the fresh suspension was 9.2 and after standing for 24 hr it was 7.7.

The fusion point of the sample was 1180°C., corresponding to Orton Cone 5. For judging the bonding characteristics of the sample, synthetic sand mixtures were prepared employing washed Rajmahal sand of fineness number 46 as the base sand and adding 5 per cent bentonite as binder. The physical characteristics of the mixture showed considerable variation with change in moisture content. Green compressive strength was maximum (8.9 lb./sq. in.) at 1.4 per cent moisture content. The value fell to 3.2 lb./sq. in. at 5.2 per cent moisture. Similarly, permeability fell from the maximum value of 240 at 2.1 per cent moisture to 160 at 5.2 per cent moisture.

The shatter index value decreased from 49.39 at 1.4 per cent moisture to 22.86 at 5.2 per cent moisture. The dry strength increased steadily from 32 lb./sq. in. at 1.4 per cent moisture to 94 lb./sq. in. at 5.2 per cent moisture. Flowability was satisfactory throughout the moisture range employed. The mixture rammed hard in the specimen tube, the maximum hardness being 87 at 1.4 per cent moisture (Table 127, Fig. 29).

TABLE 126—RAJASTHAN BENTONITE: CHEMICAL ANALYSIS

CHEMICAL CONSTITUENT	AS-RECEIVED	AFTER ORE-DRESSING
SiO ₂ , %	52.93	48.00
Al ₂ O ₃ , %	20.87	17.76
Fe ₂ O ₃ , %	8.80	8.20
TiO ₂ , %		2.24
CaO, %	0.75	1.20
MgO, %	2.38	1.20
Na ₂ O+K ₂ O, %	1.48	1.52
Loss on ignition, %	13.87	20.20

TABLE 127—RAJASTHAN BENTONITE: BONDING CHARACTERISTICS

	MOISTURE, %					
	1.4	2.1	3.0	3.6	4.8	5.2
Green permeability No.	230	240	220	195	170	160
Green compressive strength, lb./sq. in.	8.9	6.3	4.8	4.0	3.4	3.2
Green shear, lb./sq. in.	2.0	1.5	1.2	0.9	0.8	0.7
Mould hardness No.	87	83	80	78	73	66
Flowability,	78	78	78.5	78	82	77
Shatter index	49.39	34.36	31.76	30.59	27.43	22.86
Dry compressive strength, lb./sq. in.	32	41	55	73	84	94
Dry shear, lb./sq. in.	6.0	8.9	12.1	18.0	23.0	25.0
Bulk density after compression, g./cc.	1.524	1.524	1.553	1.553	1.592	1.621

The air setting properties of the sand mixture were studied by exposing rammed test pieces to laboratory atmosphere and then testing them for compressive strength at regular intervals. The values obtained up to a

TABLE 128—CRUSHING STRENGTH OF RAJMAHAL SAND BONDED WITH RAJASTHAN BENTONITE AT DIFFERENT INTERVALS OF EXPOSURE

(Initial moisture content, 3%)

PERIOD OF EXPOSURE hr	CRUSHING STRENGTH lb./sq. in.
0	4.8
0.5	7.0
1	8.0
2	9.3
3	14.1
4	19.0
5	25.0
24	46.0

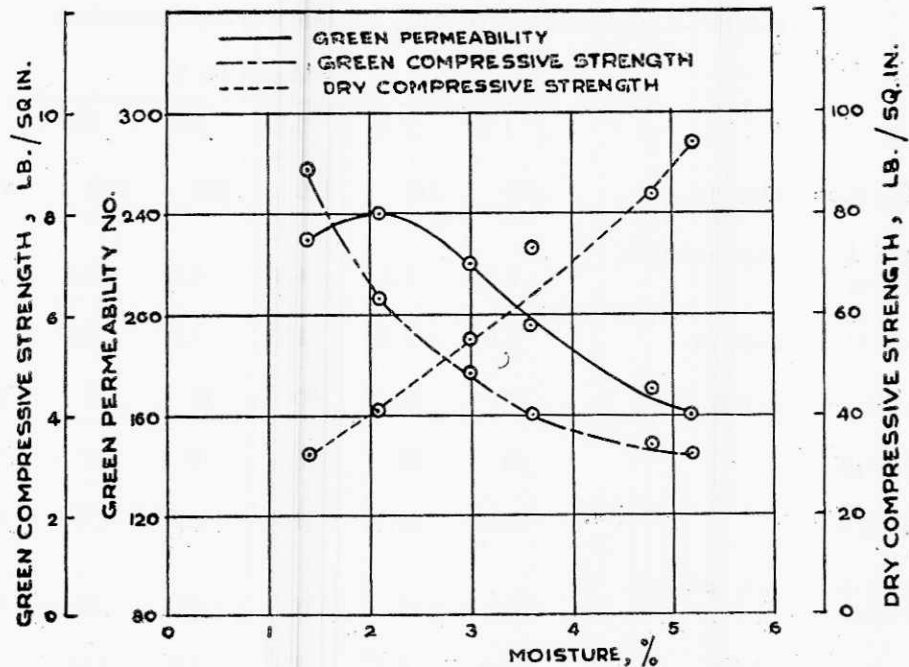


FIG. 29—RAJASTHAN BENTONITE: BONDING CHARACTERISTICS [Rajmahal sand used as base and bentonite added at 5 per cent]

period of 24 hr are presented in Table 128. It is evident that the green strength was nearly doubled after 1 hr exposure and increased ten-fold after 24 hr exposure.

Moulds of the sand mixture when used in the casting of test blocks of steel and iron gave satisfactory performance. The test blocks had smooth surfaces with no signs of burning on ; the sand layers peeled off easily. The pattern stripped well from the mould on ramming.

Conclusion. Sand mixtures bonded with Rajasthan bentonite can be employed both in the green and dried conditions for light and medium steel castings. The green sand moulds give better performance after 2-3 hr exposure to the atmosphere. The surface friability of the sand mixture may be overcome by a suitable surface coating or wash and subsequent drying.

K(1) Bentonite

The bentonite sample was supplied by *Messrs Tata Locomotive & Engineering Co. Ltd*, Tatanagar, for determining (i) the optimum proportions of the bentonite required for bonding washed Rajmahal sand so as to obtain the requisite range of physical properties for use in moulds and (ii) the optimum working moisture range for these sand mixtures for green sand moulding in steel foundry practice.

As received, the sample was in pea-size lumps, pale bluish-green in colour, and contained 10-15 per cent moisture. It was dried and pulverized in a pot mill. This yielded a product, the bulk of which passed through 200 mesh. The pulverized sample was taken up for investigation.

TABLE 129—K(1) BENTONITE: CHEMICAL ANALYSIS

CHEMICAL CONSTITUENT

SiO ₂ , %	52.44
Al ₂ O ₃ , %	17.72
Fe ₂ O ₃ , %	1.14
TiO ₂ , %	0.14
MgO, %	4.60
CaO, %	2.11
Na ₂ O+K ₂ O, %	0.86
Loss on ignition, %	20.90

The sample showed very poor swelling characteristics, the swelling index being 2.63.

The results of chemical analysis are presented in Table 129.

A suspension of 1.5 g. of the bentonite in 100 ml. distilled water showed marked alkalinity. The pH value of the fresh suspension was 8.35 and after standing for 24 hr it was 7.7.

TABLE 130—K(1) BENTONITE: BONDING CHARACTERISTICS

(Moisture content, 2.5%)

	MIXTURE 1	MIXTURE 2
Green permeability No.	215	225
Green compressive strength, lb./sq. in.	3.8	10.1
Green shear, lb./sq. in.	0.8	2.2
Mould hardness No.	75	84
Flowability, %	83	77
Shatter index	27.55	49.09
Dry compressive strength, lb./sq. in.	32	39
Bulk density after compression, g./cc.	1.524	1.505

TABLE 131—K(1) BENTONITE: BONDING EFFECT ON WASHED RAJMAHAL SAND AT DIFFERENT MOISTURE CONTENTS

	MOISTURE, %				
	2.5	3.0	3.6	5.0	6.0
Green permeability No.	225	245	220	185	145
Green compressive strength, lb./sq. in.	10.1	8.6	6.8	5.8	4.3
Green shear, lb./sq. in.	2.2	1.8	1.5	1.2	1.0
Mould hardness No.	84	84	82	80	77
Flowability, %	77	74	73.5	76.5	80
Shatter index	49.09	55.09	58.87	53.50	31.92
Dry compressive strength, lb./sq. in.	39	43	47	58	93.5
Dry shear, lb./sq. in.	7	8	9	15.5	22
Bulk density after compression, g./cc.	1.505	1.524	1.544	1.573	1.621

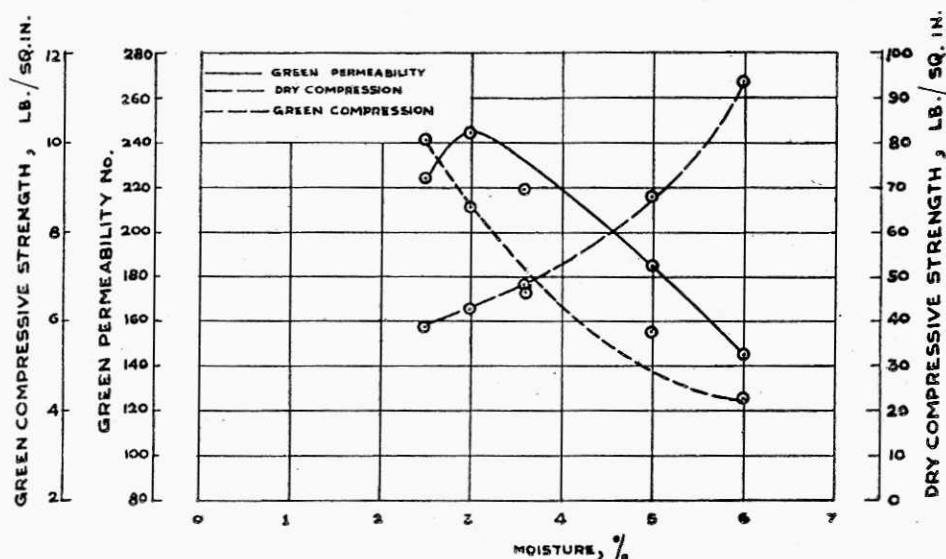


FIG. 30—K(1) BENTONITE: BONDING CHARACTERISTICS [Rajmahal sand used as base and bentonite added at 5 per cent level]

The fusion point of the sample was found to be 1290°C. Considerable expansion of the pyrometric cone sample was observed during this test.

For determining the binding characteristics of the sample, sand mixtures were prepared using washed Rajmahal sand as base, and bonding it with 3 and 5 per cent bentonite. The physical characteristics of the two mixtures are presented in Table 130. The results indicate that the sand mixture containing 5 per cent K(1) bentonite had better strength, permeability and shatter index than the one containing 3 per cent bentonite. The bonding characteristics of Mixture 2 (5 per cent bentonite) at different moisture levels are shown in Table 131 and Fig. 30.

Maximum green compressive strength (10.1 lb./sq. in.) was obtained at 2.5 per cent moisture. Permeability was maximum (245) at 3 per cent moisture and was only 145 at 6 per cent. The flowability was fairly satisfactory throughout the moisture range employed (2.5–6.0 per cent). The shatter index values were optimal (53–58) in the moisture range 3–5 per cent. The dry strength was quite low (39–47 lb./sq. in.) at moisture contents less than 3.6 per cent, but beyond this level, it showed a steady rise to a maximum of 93.5 lb./sq. in. at 6 per cent moisture. Thus, the optimum moisture range for working sands bonded with K(1) bentonite is 3–3.6 per cent for green sand moulding.

Conclusion. Optimum values of strength, permeability and shatter index are obtained by working Rajmahal sand with 5 per cent of bentonite in the moisture range 3–3.6 per cent for green sand moulding.

'R' Bentonite

The sample was also supplied by *Messrs Tata Locomotive & Engineering*

Co. Ltd., Tatanagar. It was found to have extremely poor swelling characteristics, the swelling index being 1.0.

Suspension of 1.5 g. of the bentonite in 100 ml. distilled water showed slight acidity. The pH value of the fresh suspension was 6.2 and after standing for 24 hr it was 6.9. Chemical composition of the bentonite is shown in Table 132.

The bentonite is highly refractory, the fusion point being above 1720°C.

For studying its bonding characteristics, sand mixtures were prepared using washed Rajmahal sand as base and adding 3 and 5 per cent bentonite. The bonding characteristics of the two mixtures are shown in Table 133. It is

TABLE 132—'R' BENTONITE: CHEMICAL ANALYSIS

CHEMICAL CONSTITUENT

SiO ₂ , %	42.4
Al ₂ O ₃ , %	33.08
Fe ₂ O ₃ , %	3.1
CaO, %	1.1
MgO, %	0.2
Na ₂ O+K ₂ O, %	0.37

TABLE 133—'R' BENTONITE: BONDING CHARACTERISTICS

CHARACTERISTIC	MIXTURE 1*	MIXTURE 2†
Green permeability No.	260	215
Green compressive strength, lb./sq. in.	1.4	4.4
Green shear, lb./sq. in.	0.3	0.9
Mould hardness No.	58	77.5
Flowability, %	85	80
Dry compressive strength, lb./sq. in.	9.9	10.5
Dry shear strength, lb./sq. in.	2.2	—

* Moisture content, 1.5% † Moisture content, 1.6%

evident from the results presented in Table 133, that addition of 'R' bentonite at 5 per cent level is more beneficial than at 3 per cent level.

The moulding characteristics of Mixture 2 containing 5 per cent bentonite at different moisture levels are shown in Table 134. Maximum green strength (4.4 lb./sq. in.) was obtained at a moisture content of 1.6 per cent. The value fell with increase in moisture content and was only 1.3 lb./sq. in. at 5.0 per cent moisture content.

Green permeability was maximum (240) at 2.0 per cent moisture level and fell with increase in moisture content, being 135 at 5.0 per cent level. Flowability was fairly good throughout the moisture range studied (1.6–5.0 per cent). Dry compressive and shear strengths showed a steady rise with increase in moisture content (Table 134, Fig. 31).

Conclusion. The test results indicate that the sample may be kaolinitic clay rather than montmorillonitic as it is non-swelling, highly refractory and contains a higher percentage of alumina than silica, and low percentages of alkalis and magnesia.

Rajmahal sand with 5 per cent of the bentonite can be recommended for

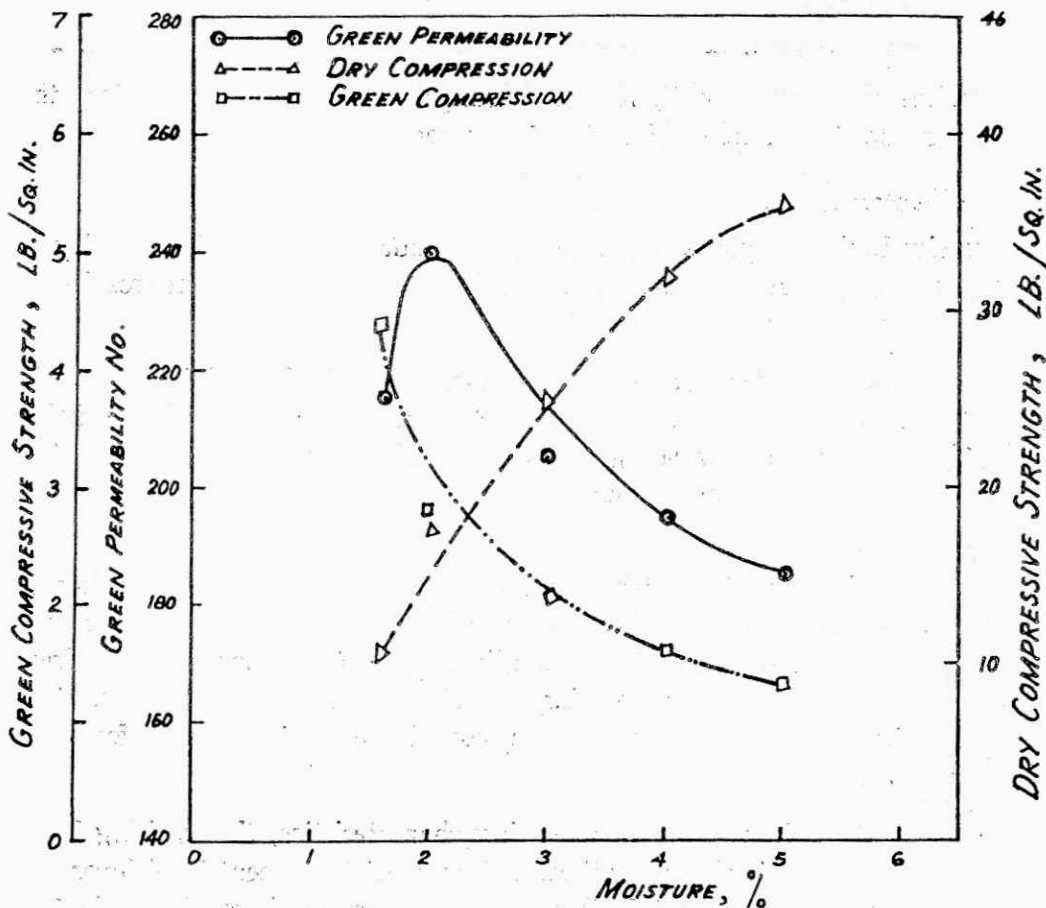


FIG. 31—'R' BENTONITE: BONDING CHARACTERISTICS [Rajmahal sand used as base and bentonite added at 5 per cent level]

TABLE 124—WASHED RAJMAHAL SAND BONDED WITH 5% 'R' BENTONITE: BONDING CHARACTERISTICS AT DIFFERENT MOISTURE CONTENTS

	MOISTURE, %				
	1.6	2.0	3.0	4.0	5.0
Green permeability No.	215	240	205	195	185
Green compressive strength, lb./sq. in.	4.4	2.8	2.0	1.6	1.3
Green shear, lb./sq. in.	0.9	0.7	0.5	0.4	0.3
Mould hardness No.	77.5	72	60	60	48
Flowability, %	80	81	84	82	83
Dry compressive strength, lb./sq. in.	10.5	18	25	32	36
Dry shear, lb./sq. in.	—	3.5	8.5	8.0	14

use in the production of light steel castings by green sand practice, the optimum moisture range being 1.5–2 per cent.

Bihar Bentonite

As received, the sample was pale grey in colour, with a specific gravity of 2.15 and an initial moisture content of 10.75 per cent. The results of chemical analysis are shown in Table 135.

Screening of the dried sample by standard method showed it to contain about 43 per cent of particles of –53 micron size, the balance being of –100 + 270 mesh. Washing tests revealed the presence of 40 per cent of sand grade particles, mostly fines, retained on 200 and 270 meshes and the pan.

Suspension of 1.5 g. of dried bentonite in 100 ml. of distilled water showed slight alkalinity. No appreciable change in pH value of the suspensions was observed even after 24 hr standing. The pH values of the fresh suspension and after 24 hr standing were 7.15 and 7.2 respectively. The principal cation in the exchange complex of the bentonite was found to be calcium.

The sample exhibited very poor swelling characteristics, the swelling index being only 1.6. Addition of sodium carbonate at 5 per cent level improved the swelling index to 4, but further additions were detrimental (Table 136, Fig. 32).

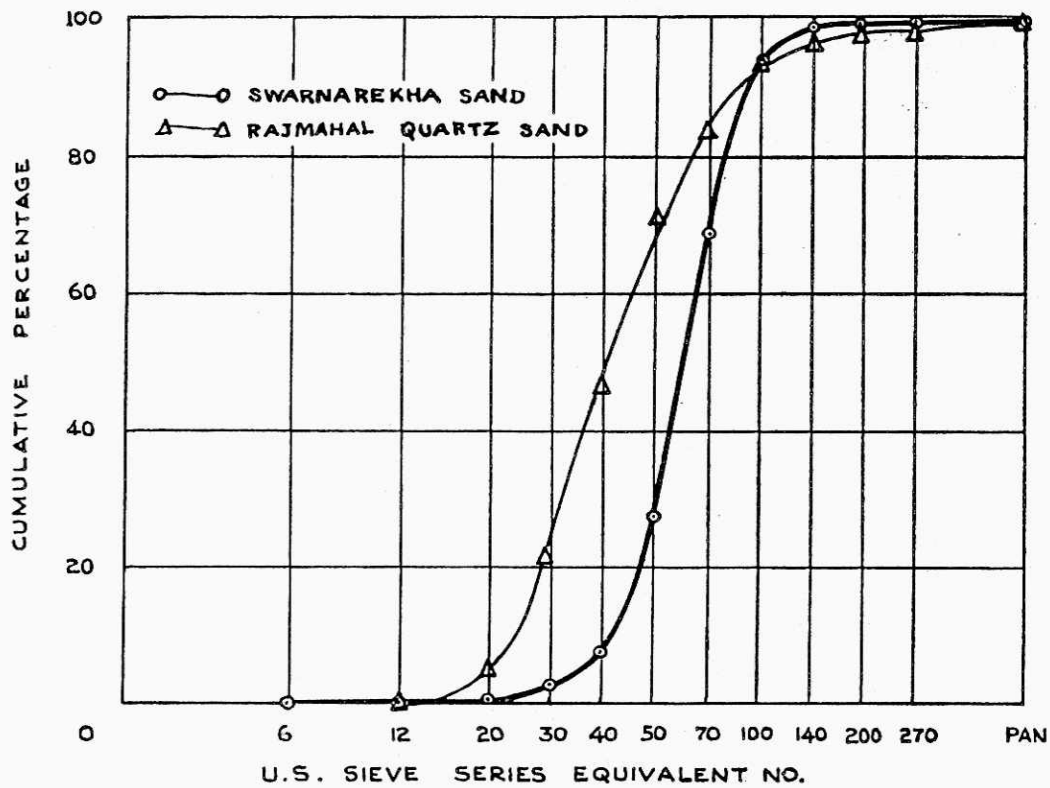


FIG. 32—SWARNAREKHA AND RAJMAHAL QUARTZ SAND: CUMULATIVE GRADING CURVES

TABLE 135—BIHAR BENTONITE: CHEMICAL ANALYSIS

CHEMICAL CONSTITUENT

SiO ₂ , %	43.90
Al ₂ O ₃ , %	23.50
Fe ₂ O ₃ , %	4.20
TiO ₂ , %	3.28
CaO, %	1.21
MgO, %	0.61
Na ₂ O+K ₂ O, %	1.48
Loss on ignition, %	21.82

The bonding characteristics of the sample were studied by bonding Swarnarekha sand (Table 137, Fig. 33) with it at 5 per cent level. Milling for 5 min. was found to be sufficient to develop the full green bond strength in the sand mixture. At moisture contents between 2.3 and 4 per cent it showed good combination of compressive strength and permeability in the green state. Maximum green strength (6.6 lb./sq. in.) and permeability (200) were attained at 2.3 and 4 per cent moisture respectively (Figs 34, 35 & 36). The dry strength values were rather poor below 4 per cent moisture and high moisture ranges and ramming densities were necessary to get satisfactory dry strength (Table 138, Figs. 37 & 38).

For comparison, the bonding characteristics of Fulbonds No. 1 and 4-A tried under similar conditions with Swarnarekha sand (5 per cent addition) are also presented in Tables 139 & 140.

It is evident that while the permeability values of Bihar bentonite are somewhat higher than that of Fulbond No. 1 its green and dry strengths are equivalent only in the case of test pieces rammed with 6 and 10 blows. The general bonding characteristics are more or less similar to those of

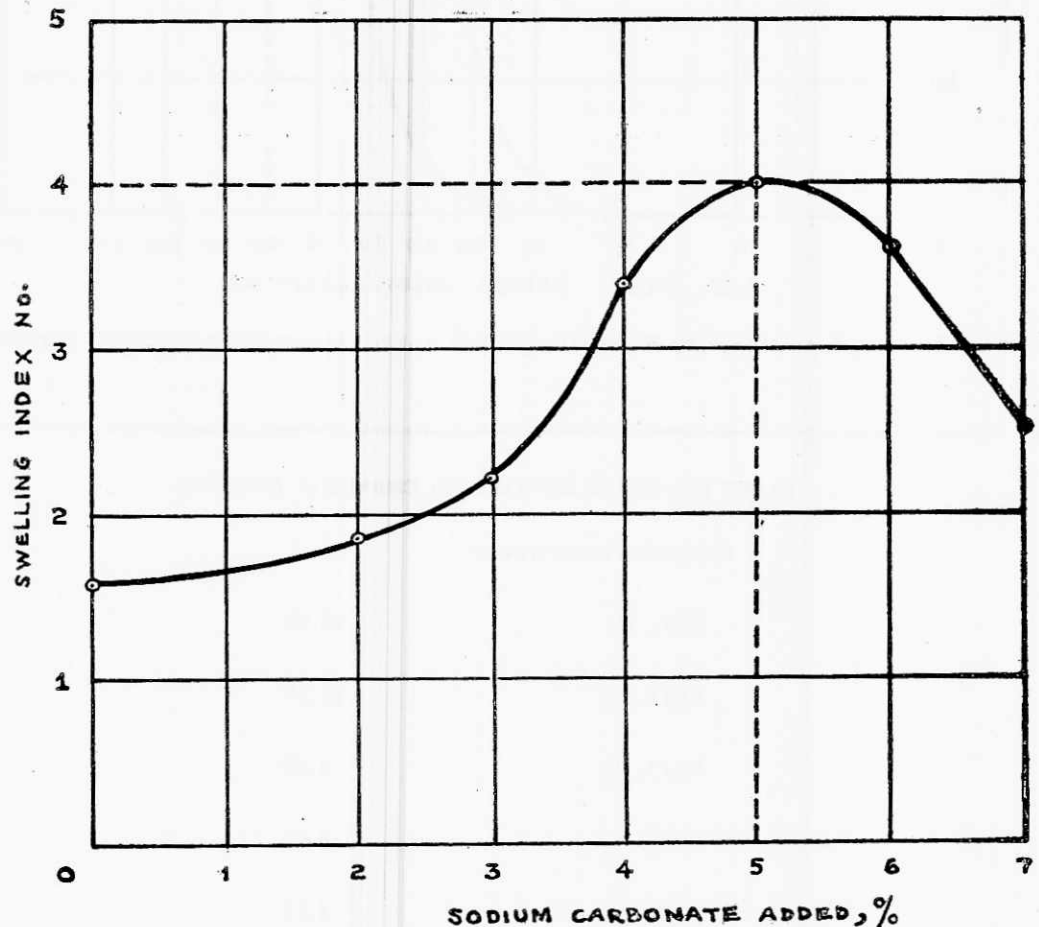


FIG. 33—BIHAR BENTONITE: SWELLING CHARACTERISTICS AS AFFECTED BY SODIUM CARBONATE ADDITION

TABLE 136—EFFECT OF SODIUM CARBONATE ADDITION ON THE SWELLING CHARACTERISTICS OF BIHAR BENTONITE

SODIUM CARBONATE ADDED, %	WT. OF SAMPLE REQUIRED TO FORM A COMPLETE THIXO- TROPIC GEL, g.	SWELLING INDEX
2	5.4	1.85
3	4.5	2.20
4	2.9	3.4
5	2.5	4.0
6	2.8	3.6
7	4.0	2.5

TABLE 137—SWARNAREKHA SAND: SIZE GRADING

U.S. SIEVE EQUIVALENT NO.	% RETAINED	CUMULATIVE %
6	Nil	—
12	Nil	—
20	0.60	0.60
30	1.73	2.33
40	4.84	7.17
50	20.76	27.83
70	40.80	68.73
100	25.17	93.90
140	4.85	98.75
200	0.60	99.35
270	0.12	99.47
Pan	0.25	99.72

Fulbond No. 1, but from the point of view of susceptibility to variations in moisture content, Bihar bentonite is slightly superior.

Superior bonding characteristics of Fulbond No. 4-A, especially the improvement in green and dry strengths at low moisture contents, are evident from the results presented in Table 140.

TABLE 138—SWARNAREKHA SAND BONDED WITH 5% BIHAR BENTONITE: BONDING CHARACTERISTICS

MOISTURE %	BULK DENSITY		GREEN PERMEABILITY No.	GREEN COMPRESSIVE STRENGTH, <i>lb./sq. in.</i>			GREEN SHEAR <i>lb./sq. in.</i>			DRY COMPRESSIVE STRENGTH, <i>lb./sq. in.</i>			DRY SHEAR <i>lb./sq. in.</i>		
	Before compression <i>g./cc.</i>	After compression <i>g./cc.</i>		No. of Rams			No. of Rams			No. of Rams			No. of Rams		
				3	6	10	3	6	10	3	6	10	3	6	10
2.0	1.02	1.37 1.39 1.44	150 130 120	5.8	9.5	11.5	1.4	1.5	1.7	9	13	19	2	2.2	4.26
2.3	0.88	1.37 1.39 1.44	190 160 142	6.6	9.5	11.5	1.2	1.4	1.5	10	14	22	3	3.5	4
3.4	0.82	1.40 1.45 1.48	193 167 147	4.5	6.5	9.0	0.9	1.0	1.3	22.5	30.5	30.8	4.3	4.9	6
4.0	0.768	1.42 1.47 1.48	200 167 150	3.8	5.2	6.3	0.8	0.9	1.1	25	33	45	6	7.5	8.75
4.5	0.768	1.42 1.48 1.50	200 165 137	3.5	5.0	6.4	0.6	0.8	1.0	30	46	59	7.2	8	9.8
4.7	0.768	1.44 1.48 1.50	192 162 137	3.25	4.4	5.85	0.6	0.8	1.0	32	54	65	9	14	15.5
5.8	0.78	1.44 1.50 1.52	182 150 128	2.65	3.55	5.45	0.6	0.8	0.9	52	68	82	1.25	15.5	18.75
7.0	0.8	1.47 1.50 1.53	158 130 120	2.25	3.25	4.6	0.6	0.8	0.9	76.5	95	111.4	17.5	22	27
0.2	0.86	1.48 1.52 1.56	150 130 120	1.9	2.4	3.4	0.5	0.6	0.8	91.5	—	—	25	29.3	35.5

Bonding characteristics of sodium carbonate treated Bihar bentonite were also studied employing Swarnarekha sand as base, with a view to find out whether there is any improvement in this respect as a result of base exchange. The results are presented in Table 141.

It is evident that treatment with sodium carbonate results in no noticeable increase in the dry strength characteristics, though the plasticity, permeability and green strength show some improvement. Maximum permeability (208) and green strength (7.55 lb./sq. in.) were attained at 3.2 and 2 per cent moisture contents respectively as compared to the permeability value of 193 and green strength of 5.8 lb./sq. in. obtained without the addition of sodium carbonate.

The effect of drying temperature on the dry strength characteristics of Bihar bentonite was studied by baking sand specimens (2 in. $\times$ 2 in.) made from Bihar bentonite (5 per cent)-Swarnarekha sand mixture at different temperatures in the range 100–350°C. in Dietert core baking oven and

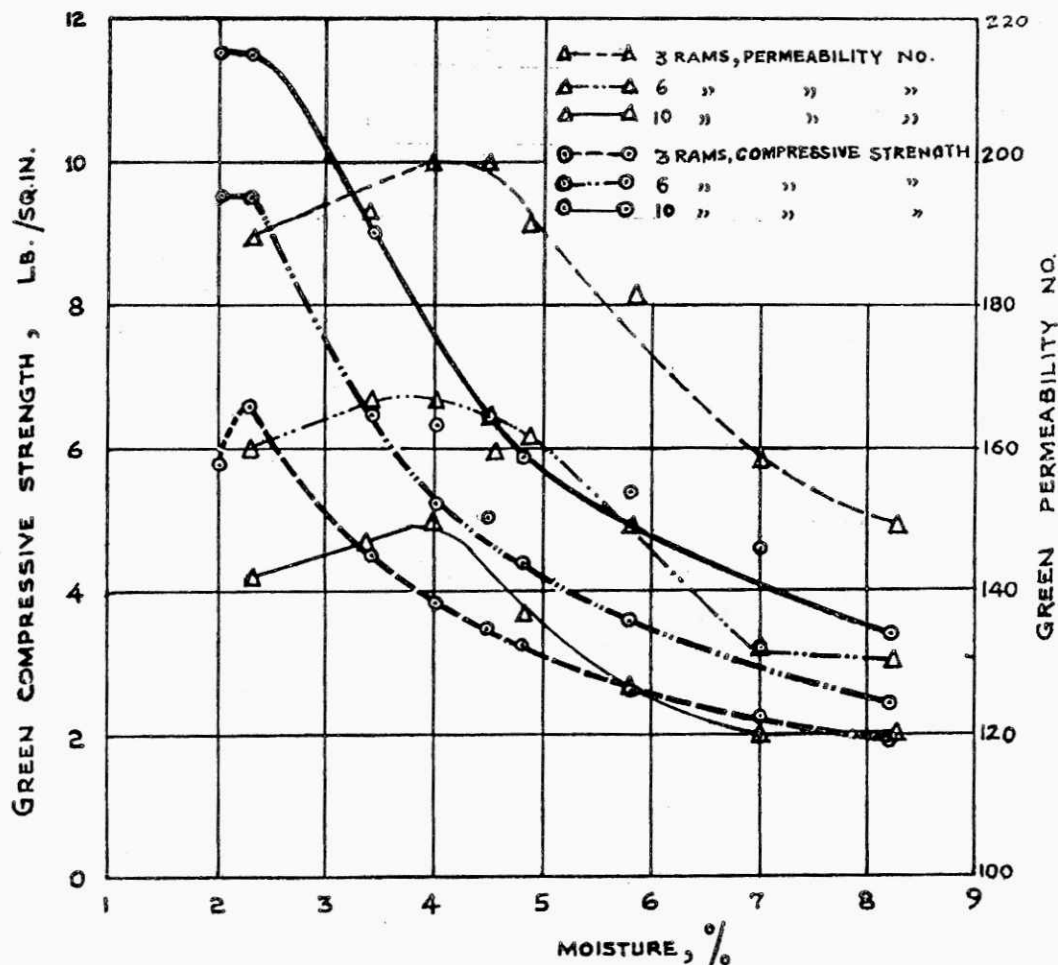


FIG. 34—BIHAR BENTONITE-SWARNAREKHA SAND MIXTURE (5:95): GREEN PERMEABILITY AND GREEN STRENGTH AT DIFFERENT MOISTURE CONTENTS

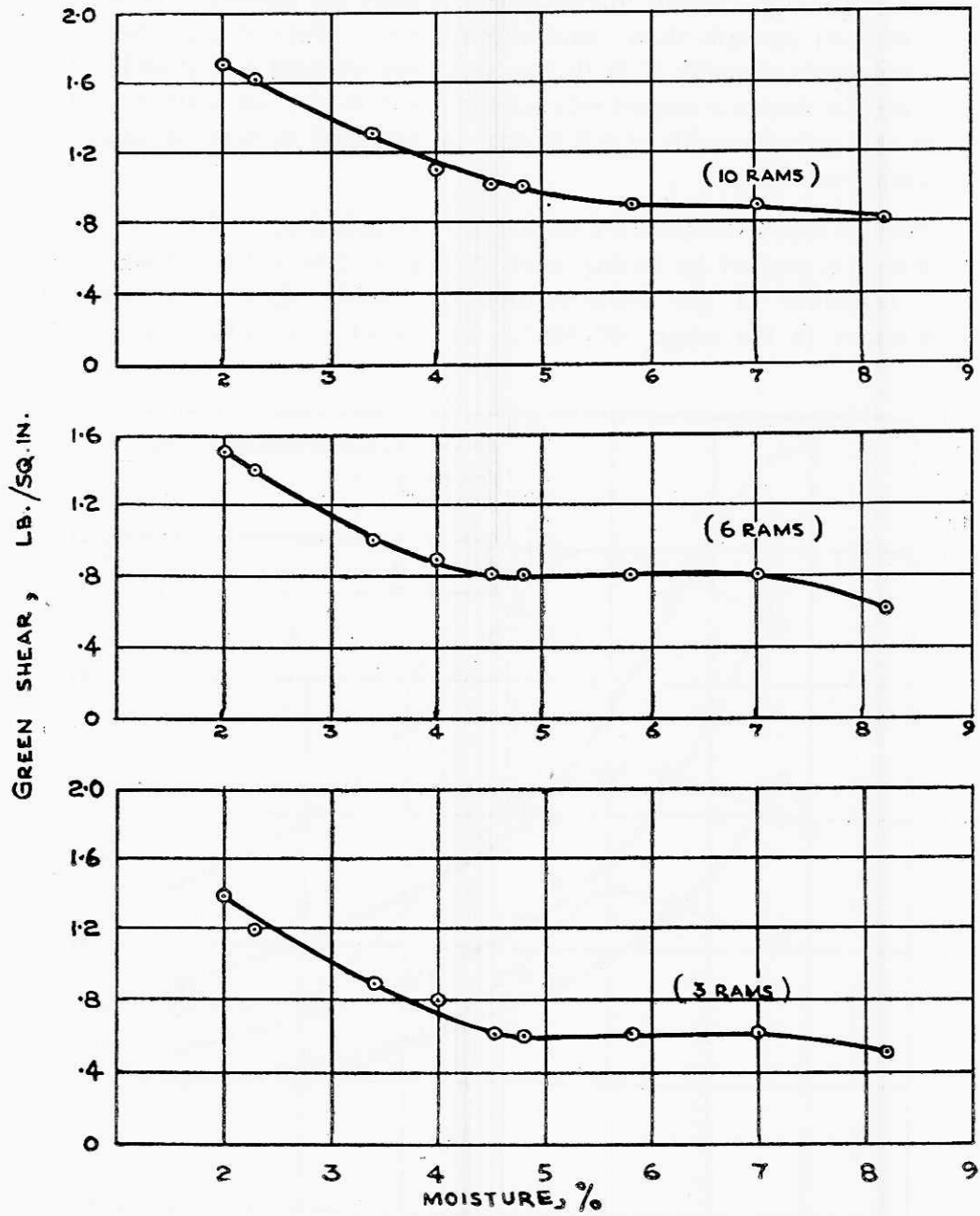


FIG. 35—BIHAR BENTONITE-SWARNAREKHA SAND MIXTURE (5 : 95): GREEN SHEAR AT DIFFERENT MOISTURE CONTENTS

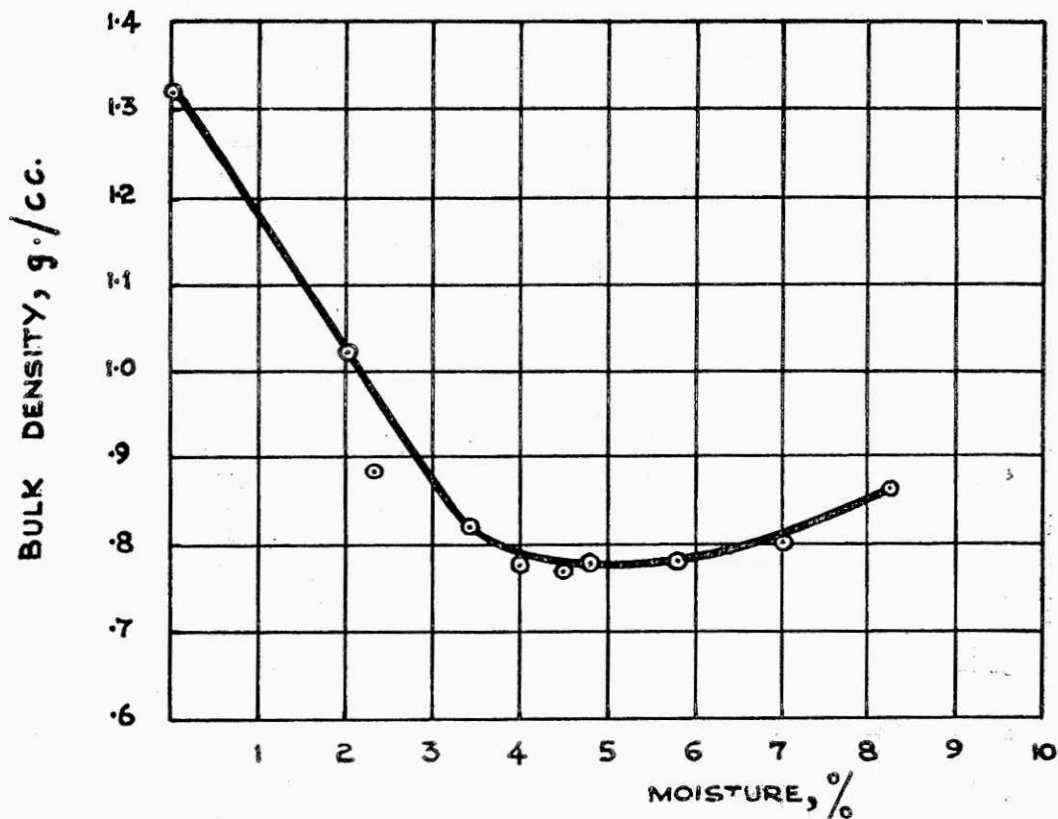


FIG. 36—BIHAR BENTONITE-SWARNAREKHA SAND MIXTURE (5:95): BULK DENSITY PRIOR TO COMPRESSION AT DIFFERENT MOISTURE CONTENTS

TABLE 139—FULBOND No. 1 SWARNAREKHA SAND MIXTURE (5:95): BONDING CHARACTERISTICS AT DIFFERENT MOISTURE CONTENTS

MOISTURE %	GREEN PERMEABI- LITY No.	GREEN COM- PRESSIVE STRENGTH lb./sq. in.	GREEN SHEAR STRENGTH lb./sq. in.	DRY COM- PRESSIVE STRENGTH lb./sq. in.	DRY SHEAR STRENGTH lb./sq. in.
1.2	130	4.5	0.8	—	—
1.6	133	6.2	1.1	9	3.0
1.7	135	6.5	1.1	15	4.0
2.2	145	7.5	1.3	22	4.8
2.5	145	6.25	1.0	25	6.0
3.0	140	5.5	0.9	38	7.5
3.8	135	4	0.8	49	9.5
4.5	133	3.5	0.65	63	20
5.2	130	2.9	0.5	80	29
7.0	125	1.6	0.3	93	30

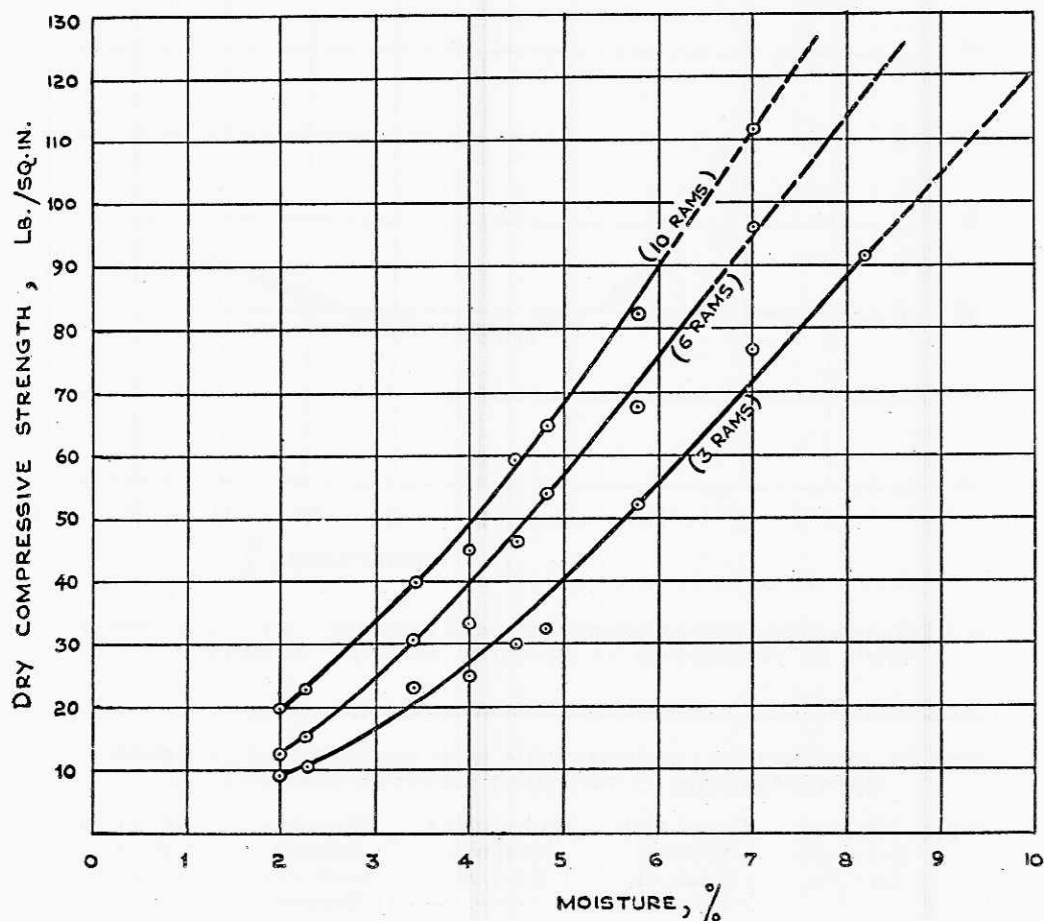


FIG. 37—BIHAR BENTONITE-SWARNAREKHA SAND MIXTURE (5:95): DRY STRENGTH AT DIFFERENT MOISTURE CONTENTS

determining the compressive strengths of the dried pieces. The results given in Table 142 indicate that drying at 150°C. gives maximum dry strength. Baking at temperatures beyond 300°C., however, lowers the dry strength considerably.

For studying the air setting properties of bonded Swarnarekha sand, rammed test pieces were exposed to the laboratory atmosphere for varying intervals. Green compressive strengths obtained are shown in Table 143. The green strengths increased rapidly at first, the strength after 1 hr exposure being nearly double the original value. Further exposure resulted in a gradual increase, the values after 4 hr and 24 hr being approximately 3 and 5 times the original value.

The bonding effect of Bihar bentonite on Rajmahal quartz sand [size grading given in Table 78(a)] was also studied with 5 per cent additions of the bentonite. The results are shown in Table 144 and Figs. 39-41.

The bonding characteristics of a well-known American bentonite—Southern bentonite (Panther Creek)—when studied on Michigan city sand (5 per cent

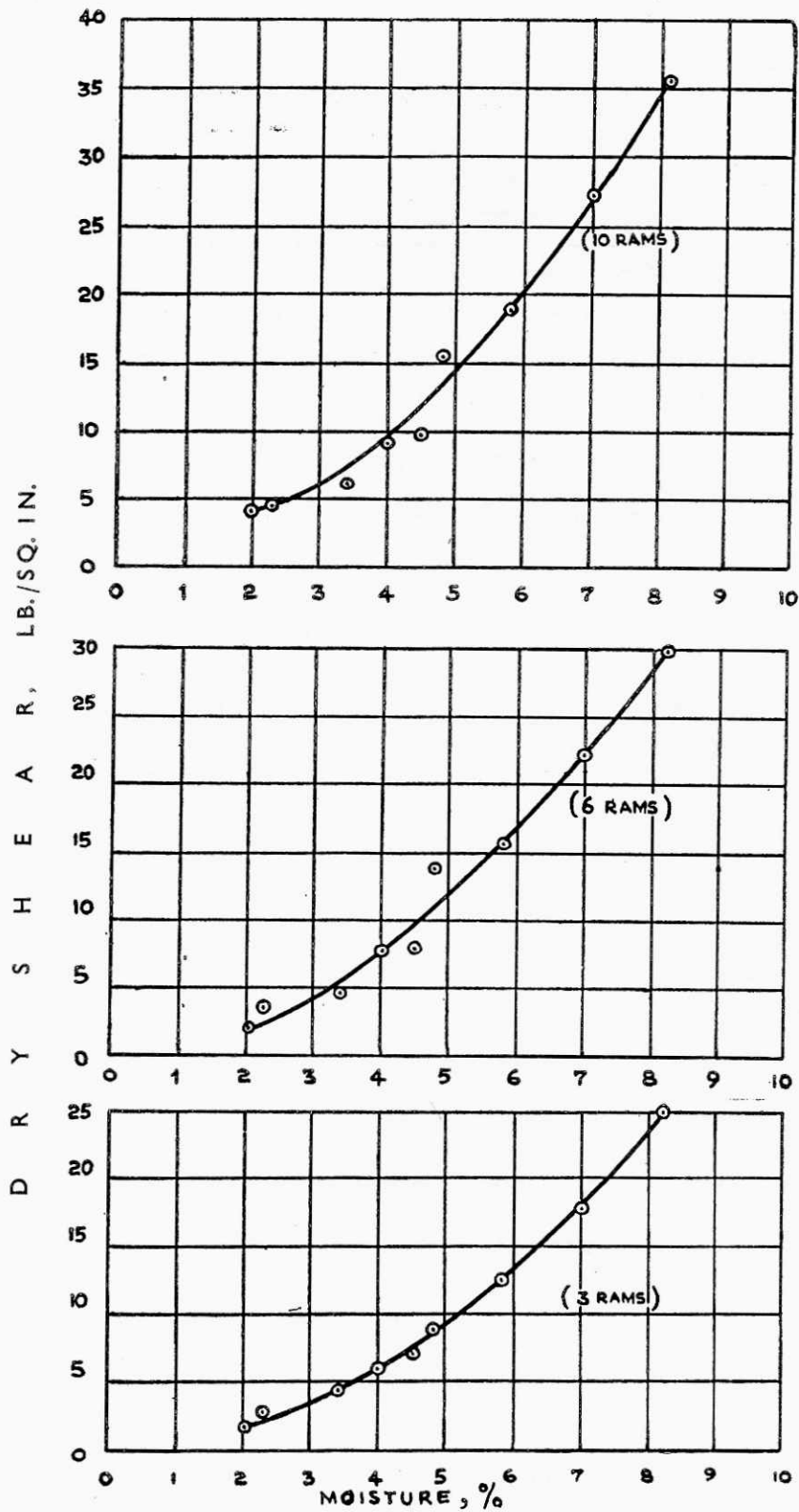


FIG. 38—BIHAR BENTONITE-SWARNAREKHA SAND MIXTURE (5 : 95): DRY SHEAR AT DIFFERENT MOISTURE CONTENTS FOR 3, 6 AND 10 RAMS [Test pieces dried at 200°C. for 2 hr]

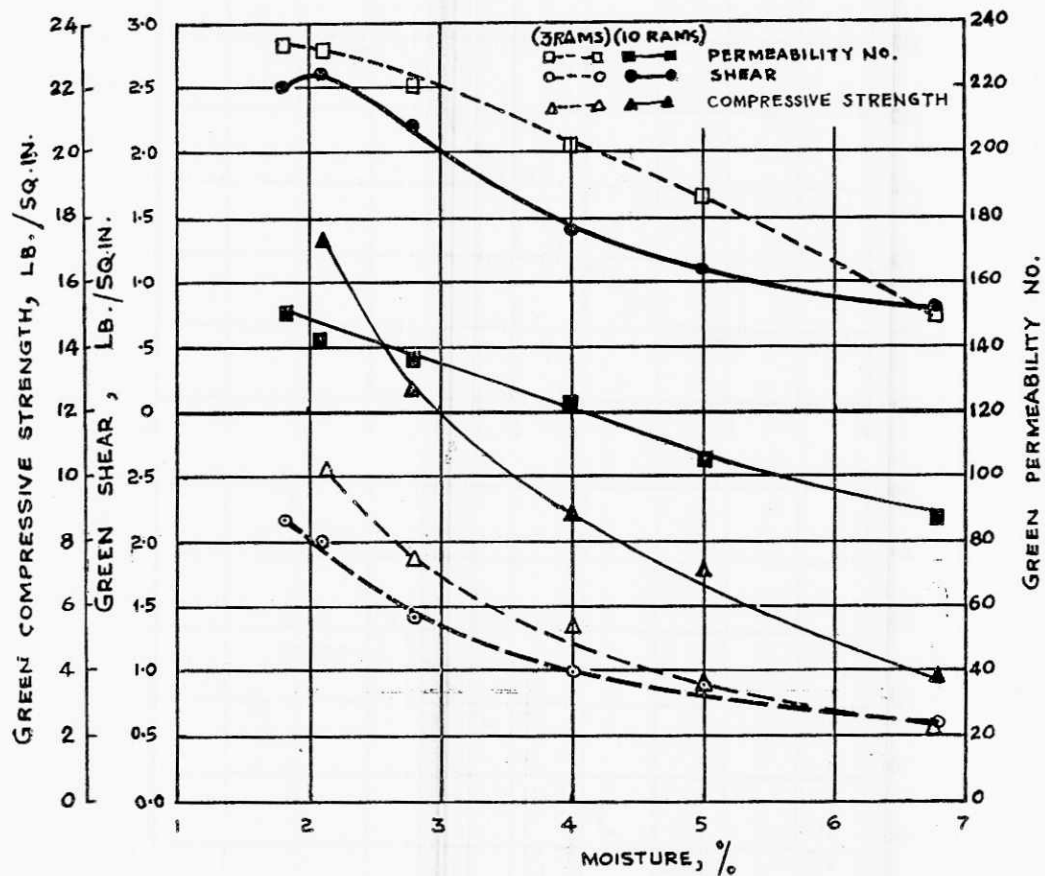


FIG. 39—BIHAR BENTONITE-RAJMAHAL QUARTZ SAND MIXTURE (5 : 95): GREEN PERMEABILITY, GREEN STRENGTH AND GREEN SHEAR AT DIFFERENT MOISTURE CONTENTS

TABLE 140—FULBOND No. 4-A SWARNAREKHA SAND MIXTURE (5:95): BONDING CHARACTERISTICS

MOISTURE %	GREEN PERMEABILITY No.	GREEN COM-PRESSIVE STRENGTH lb./sq. in.	GREEN SHEAR STRENGTH lb./sq. in.	DRY COM-PRESSIVE STRENGTH lb./sq. in.	DRY SHEAR STRENGTH lb./sq. in.
1.5	153	7.5	0.54	—	—
2.0	158	10.8	1.8	15	3.0
2.5	170	9.8	1.7	26	5.7
3.0	195	9.0	1.6	40	7.75
3.5	188	8.4	1.5	51	9.5
4.0	180	7.8	1.5	60	10.5
4.5	175	7.2	1.4	68	11.5
5.0	170	7.0	1.35	72	12.0
5.5	168	6.3	1.25	76	12.5
6.5	162	6.4	1.2	85	14.0
7.5	156	6.0	1.2	91	16.0
10.0	125	4.5	1.1	93	22.0

TABLE 141—BIHAR BENTONITE—SWARNAREKHA SAND—SODIUM CARBONATE MIXTURE (5:95:5): BONDING CHARACTERISTICS
AT DIFFERENT MOISTURE CONTENTS

MOISTURE %	BULK DENSITY		GREEN PERMEABILITY No.	GREEN COMPRESSION lb./sq. in.	GREEN SHEAR lb./sq. in.	DRY COMPRESSION lb./sq. in.	DRY SHEAR lb./sq. in.
	Before compression g./cc.	After compression g./cc.					
		No. of Rams 3 10	No. of Rams 3 10	No. of Rams 3 10	No. of Rams 3 10	No. of Rams 3 10	No. of Rams 3 10
2	1.1021	1.38 1.42	186 138	7.55 13.1	1.1 1.8	8.3 11.0	1.3 1.8
2.6	0.860	1.38 1.45	195 140	7.5 12.7	1.2 1.9	12.25 25	2.45 4.1
3.2	0.763	1.38 1.45	208 148	6.5 12.1	1.1 1.9	22.25 43	5 6.25
4.4	0.685	1.398 1.48	200 137	5.6 10.6	1.1 1.7	43.25 82.25	8.35 11.65
5.4	0.658	1.42 1.50	198 135	5.2 8.8	1.0 1.55	48 —	10.65 18.2
6.5	0.676	1.44 1.52	180 118	4.6 8.5	1.0 1.45	69.25 —	12.6 26.5
7.6	0.695	1.48 1.55	162 110	3.8 7.4	0.95 1.3	91 —	—

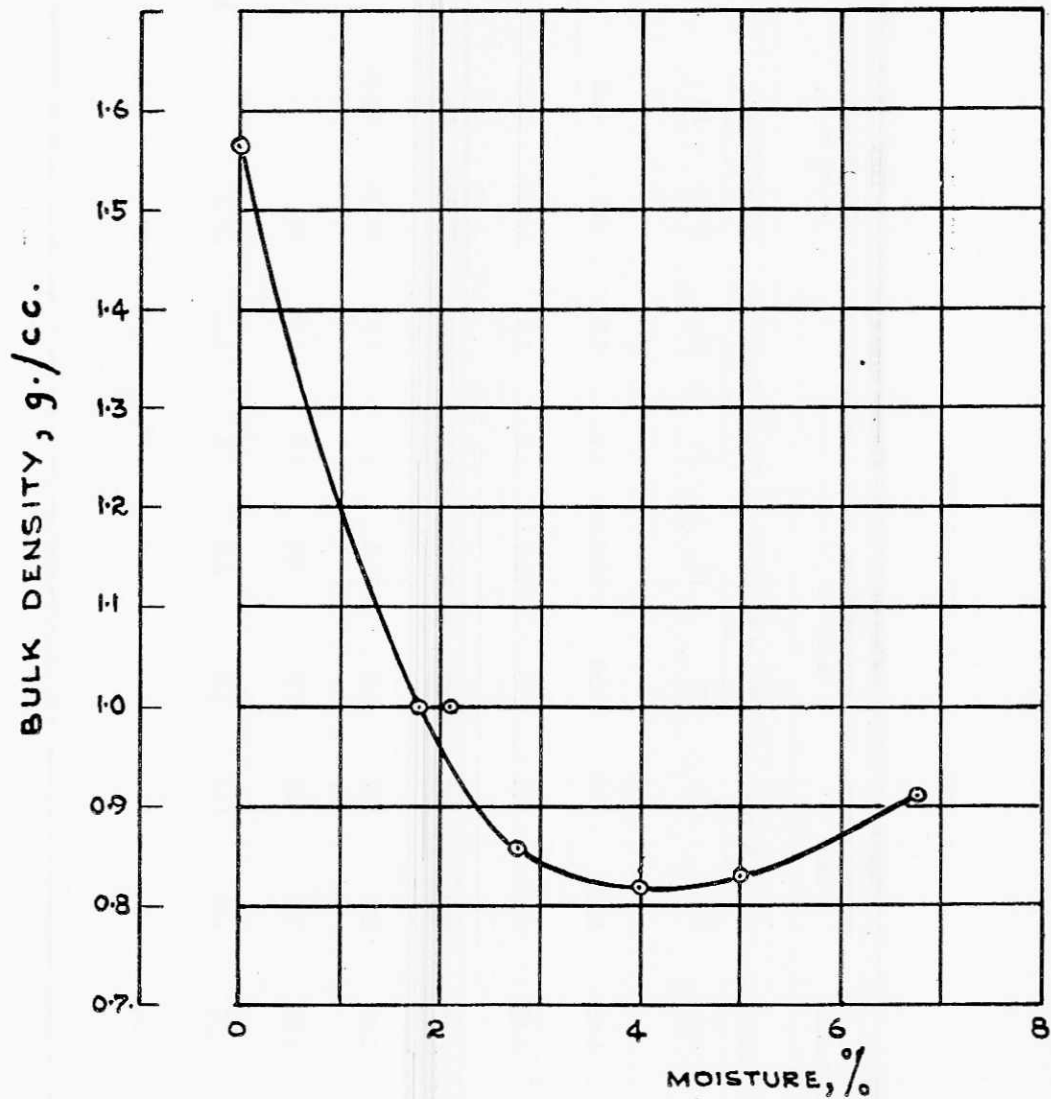


FIG. 40—BIHAR BENTONITE-RAJMAHAL QUARTZ SAND MIXTURE (5 : 95): BULK DENSITY PRIOR TO COMPRESSION AT DIFFERENT MOISTURE CONTENTS

TABLE 142—EFFECT OF DRYING TEMPERATURE ON THE DRY STRENGTH OF BIHAR BENTONITE

(Initial moisture content, 3.4%)

DRYING TEMP. °C.	DRY COMPRESSIVE STRENGTH lb./sq. in.
105-110	21.5
150	28.0
200	22.75
250	21.75
300	16.5
350	12.5

addition) are evident from the following values reported in literature: Green permeability No., 180 ; green compressive strength, 11.7 lb./sq. in. and dry compressive strength, 45 lb./sq. in.

It is evident from Table 144 that in the case of Bihar bentonite-Rajmahal sand mixture, permeability and strength, both in green and dry states, are higher than the values obtained from Bihar bentonite-Swarnarekha sand mixture. It is also evident that Bihar bentonite when used for bonding Rajmahal quartz sand gives comparable values in respect of strength and permeability to those of Southern bentonite. In the case of Swarnarekha sand mixture, however, slightly higher ramming densities are required for getting equivalent values. The optimum moisture range for working the Bihar bentonite-Rajmahal sand mixture is 2.5–3 per cent. The physical properties of the mixture are, however, fairly susceptible to variation with moisture content (Figs. 39–41).

The effect of dextrine addition on the moulding characteristics of Bihar

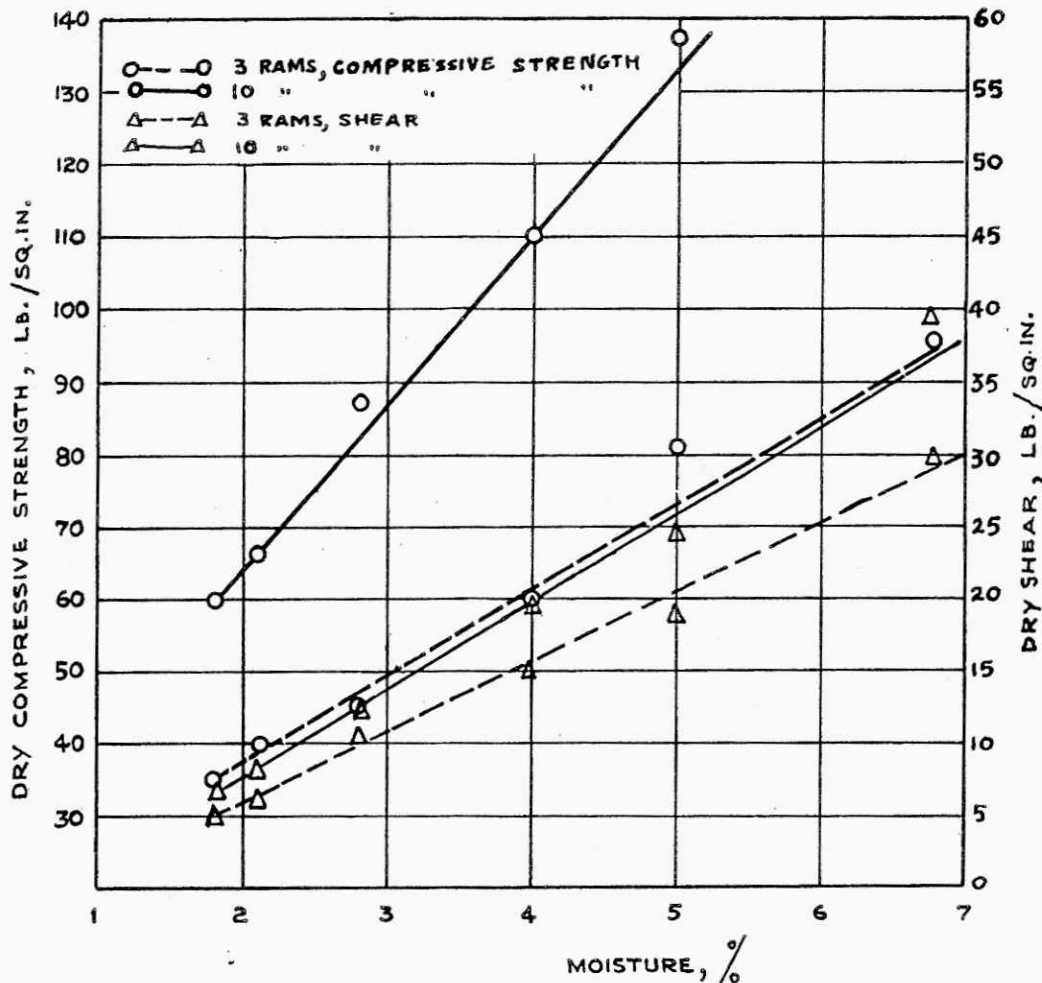


FIG. 41—BIHAR BENTONITE-RAJMAHAL QUARTZ SAND MIXTURE (5 : 95): DRY STRENGTH AND DRY SHEAR AT DIFFERENT MOISTURE CONTENTS [Test pieces dried at 200°C. for 2 hr]

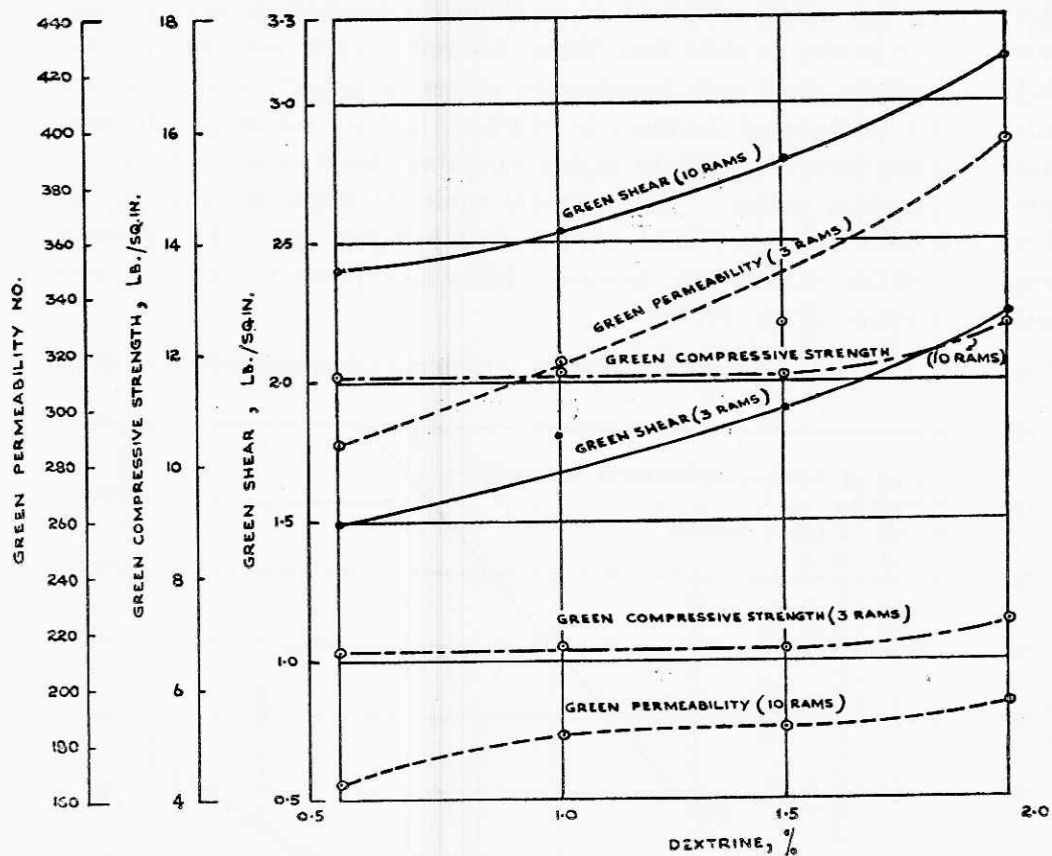


FIG. 42—BIHAR BENTONITE-RAJMAHAL QUARTZ SAND MIXTURE (5 : 95): BONDING CHARACTERISTICS AS AFFECTED BY DEXTRINE ADDITION [Moisture content, 2.4 per cent]

TABLE 143—BIHAR BENTONITE—SWARNAREKHA SAND MIXTURE (5:95): SETTING PROPERTIES

PERIOD OF EXPOSURE <i>hr</i>	GREEN COMPRESSIVE STRENGTH AFTER EXPOSURE <i>lb./sq. in.</i>	MOISTURE CONTENT AFTER EXPOSURE %
0	4.2	3.7
1/6	5.7	3.5
1/4	5.8	3.3
1/2	6.5	3.2
3/4	7.8	3.2
1	8.3	3.0
1½	8.8	2.8
2	9.5	2.8
2½	11.0	2.6
3	11.6	2.5
3½	13.0	2.2
4	13.5	2.2
4½	13.75	2.0

Contd.

PERIOD OF EXPOSURE <i>hr</i>	GREEN COMPRESSIVE STRENGTH AFTER EXPOSURE <i>lb./sq. in.</i>	MOISTURE CONTENT AFTER EXPOSURE %
5	14.7	2.0
6	16	1.9
7	17.8	1.8
8	18.5	1.8
9	19.25	1.5
10	21	1.4
12	23.25	1.3
24	21	0.9
48	20.75	0.8

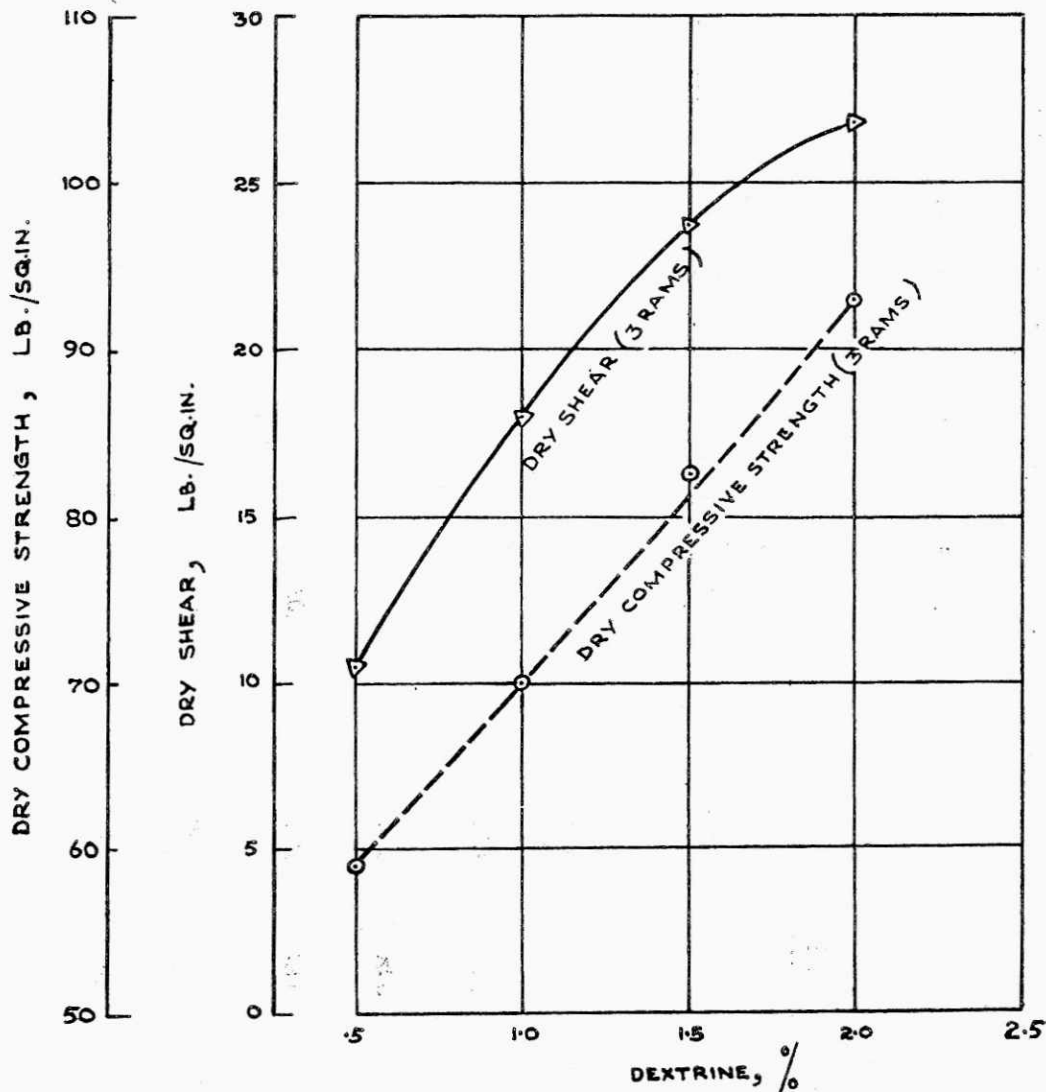


FIG. 43.—BIHAR BENTONITE-RAJMAHAL QUARTZ SAND MIXTURE (5 : 95): DRY COMPRESSIVE STRENGTH AND DRY SHEAR AS AFFECTED BY DEXTRINE ADDITION [Moisture content, 2.4 per cent ; test pieces dried at 200°C, for 2 hr]

TABLE 144—BIHAR BENTONITE—RAJMAHAL QUARTZ SAND (5:95): BONDING CHARACTERISTICS

(Maximum vol. of shatter index at 4% moisture, 47)

MOISTURE %	BULK DENSITY BEFORE COMPRESSION g./cc.	BULK DENSITY AFTER COMPRESSION g./cc.	GREEN PERMEABILITY No.	GREEN COMPRESSION lb./sq. in.	GREEN SHEAR lb./sq. in.	DRY COMPRESSION lb./sq. in.	DRY SHEAR lb./sq. in.					
		No. of Rams 3 10	No. of Rams 3 10	No. of Rams 3 10	No. of Rams 3 10	No. of Rams 3 10	No. of Rams 3 10					
1.8	1.0	1.54	235	150	9.8	16.65	2.16	2.5	35.0	60	5.2	6.5
2.1	1.0	1.57	231	143	14.3	17.45	2.0	2.0	40.0	60.0	6.25	8.3
2.8	0.86	1.58	221	138	7.6	12.85	1.4	2.2	45.0	87.5	10.5	12.5
4.0	0.82	1.62	203	125	5.5	9.0	1.0	1.4	60	110	15	20
5.0	0.83	1.64	187	107	3.65	7.2	0.8	1.1	81.5	138	19	24.5
6.8	0.91	1.75	149	88	2.5	4.0	0.6	0.8	96	—	29.75	39

TABLE 145—BIHAR BENTONITE.—RAJMAHAL QUARTZ SAND: BONDING CHARACTERISTICS AS AFFECTED BY DEXTRINE.

DEXTRINE ADDED %	BULK DENSITY BEFORE COMPRESSION g./cc.	BULK DENSITY AFTER COMPRESSION g./cc.	GREEN PERMEABILITY No.	GREEN COMPRESSIVE STRENGTH lb./sq. in.	GREEN SHEAR lb./sq. in.	DRY COMPRESSIVE STRENGTH lb./sq. in.*	DRY SHEAR lb./sq. in.*	SHATTER INDEX VALUE
		No. of Rams 3 10	No. of Rams 3 10	No. of Rams 3 10	No. of Rams 3 10			
0.5	0.8	1.54 1.65	288 167	6.7 11.65	1.5 2.4	59	10.5	53
1.0	0.78	1.52 1.64	317 184	6.8 11.65	1.8 2.55	70	18	62.8
1.5	0.747	1.52 1.64	330 186	6.7 11.6	1.9 2.8	82.5	23.75	78.8
2.0	—	1.5 1.62	396 195	7.2 12.5	2.25 3.15	93	26.75	95

* 3 Rams

bentonite-Rajmahal quartz sand mixture was also studied. Addition of 2 per cent dextrine considerably improved the general bonding characteristics, particularly the dry strength, plasticity and shatter index values (Table 145, Figs. 42 & 43). Test pieces after ramming showed marked improvement in surface characteristics as compared to test pieces prepared from the mixture without the addition of dextrine.

Casting characteristics of Bihar bentonite-sand mixtures were found to be satisfactory. No signs of 'burning on' were observed in castings of up to 1 in. section. The mixture had a fairly high refractoriness, the fusion point being 1510°C. , corresponding to Orton Cone 19.

Conclusion. This bentonite gives satisfactory performance as a bonding material for foundry sands to be used for grey iron and steel castings.