

Chapter Six

CRUDE SILICA SANDS

Hardwar Sand

The sand sample, collected from the bed of the river Ganga near Hardwar, was received through the Ordnance Factory, Muradnagar. Deposits of this sand belong to the Pliocene and Miocene strata of the Upper Tertiary system. As received, the sand was light grey in colour and contained perceptible amounts of mica. It belonged to medium 'fine' grade. The sand grains were mostly subangular to rounded, the rounded grains predominating on finer meshes (Plate V). The grains were multicoloured and plenty of mica was present as transparent flakes, especially in the coarser fractions. The size grading and fineness characteristics of the sand are shown in Tables 52(a) & 52(b). Cumulative grading curves for the raw and washed sand are shown in Fig. 11.

Petrological examination revealed the sand to consist essentially of quartz ; light minerals present were muscovite, biotite, chlorite and other ferro-magnesian minerals, while among the heavy minerals, garnet, ilmenite, magnetite, augite, sillimanite, rutile and zircon were present in order of decreasing abundance. Feldspar was present in traces. Results of chemical analysis of the sand are presented in Table 53.

The sand had a low refractoriness, the fusion temperature being 1579°C., corresponding to Orton Cone 26. Standard test pieces (2 in. × 2 in.) fired at different temperatures in the range 1150–1550°C. showed a slight overall increase in volume. Vitrification of the sand grains was observed in the case of test pieces fired at and above 1250°C. The ultimate crushing strength of the fired specimens varied from 325 to 1005 lb./sq. in. When bonded with Bihar bentonite to the extent of 5 per cent, the sand grains sintered in the range 1250–1300°C.

Moulding characteristics of the sand mixture containing 5 per cent Bihar bentonite at different moisture contents are shown in Table 55. It is evident that maximum green compressive strength (9.25 lb./sq. in.) was attainable at 7.4 per cent moisture content. The dry strength steadily increased from 66 lb./sq. in. at 2.4 per cent moisture to 163.5 lb./sq. in. at 7.4 per cent moisture. Permeability was in general low and more or less steady throughout the moisture range studied (2.4–7.4 per cent), the average value being 85. Flowability was fairly satisfactory. The shatter index was maximum (32.97) at 5.6 per cent moisture. The mixture rammed hard

TABLE 52(a)—HARDWAR SAND: SIZE GRADING

U.S. SIEVE EQUIVALENT No.	% RETAINED	
	As-received	After washing
6	Nil	Nil
12	1.28	1.36
20	5.13	2.54
30	4.53	2.34
40	11.28	7.94
50	29.74	24.38
70	27.37	29.16
100	13.24	17.74
140	5.07	8.90
200	1.24	2.82
270	0.32	0.90
Pan	0.51	0.82

TABLE 52(b)—HARDWAR SAND: FINENESS CHARACTERISTICS

CHARACTERISTIC	AS-RECEIVED	AFTER WASHING
Clay, %	—	1.04
Clay class	—	B
Grain fineness No.	48.83	57.06
Grain class No.	6	5
Max. retention on 50, 70 and 100 mesh sieves, %	70.35	71.28
Fines, %	2.07	4.54

TABLE 53—HARDWAR SAND: CHEMICAL ANALYSIS

CHEMICAL CONSTITUENT	AS-RECEIVED
SiO ₂ , %	89.4
Al ₂ O ₃ , %	4.07
Fe ₂ O ₃ , %	2.04
TiO ₂ , %	0.19
CaO, %	0.75
MgO, %	0.55
Na ₂ O, %	0.28
K ₂ O, %	1.10
Loss on ignition, %	1.20

CUMULATIVE PERCENTAGE

TABLE

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TEMP

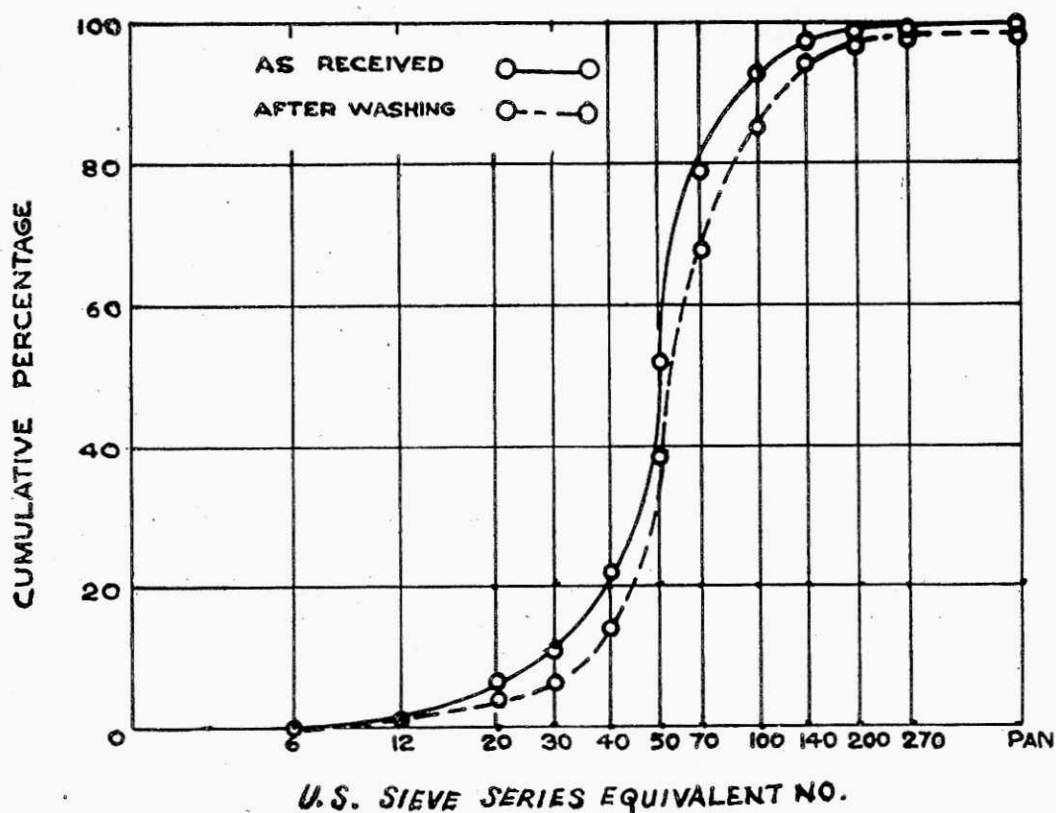


FIG. 11—HARDWAR SAND: CUMULATIVE GRADING CURVES

TABLE 54—HARDWAR SAND BONDED WITH 5% BIHAR BENTONITE: HIGH TEMPERATURE CHARACTERISTICS

(Soaking period, 1.5 hr)

FIRING TEMP., °C.	CHARACTERISTICS OF TEST PIECES AFTER FIRING	ULTIMATE CRUSHING STRENGTH, lb./sq.in.
1150	Light brown colour, surfaces friable; dull brick sound when tapped by hand, no cracks, corners more friable than surfaces; indications of commencement of vitrification	325
1250	Brown colour, cracks; low metallic sound when tapped by hand; surfaces slightly friable; vitrification	425
1350	Deep brown colour; clear metallic sound on striking; cracks; not friable	1229
1450	Deep brown colour; considerable shrinkage with cracks	1695
1550	Dark brown colour with a golden yellow tinge; completely deformed and fused with the base	—

TABLE 55—HARDWAR SAND BONDED WITH 5% BIHAR BENTONITE: MOULDING CHARACTERISTICS AT DIFFERENT MOISTURE CONTENTS

CHARACTERISTIC	MOISTURE, %					
	2.4	3.3	4.4	5.6	6.3	7.4
Green permeability No.	85	85	84	85	87	87
Green compressive strength, lb./sq. in.	9.25	7.4	5.6	5.1	3.8	3.1
Green shear, lb./sq. in.	2.1	1.5	1.3	1.05	0.9	0.7
Mould hardness No.	87	84	78	75	72	65
Flowability, %	76	78	78	78	78	77
Shatter index	27.43	27.94	30.00	32.97	26.74	21.69
Dry compressive strength, lb./sq. in.	66	77	90	115	123	163.5
Dry shear, lb./sq. in.	7.8	15.5	23.5	30.5	33.0	37.5
Bulk density, g./cc.	1.603	1.641	1.650	1.699	1.719	1.738

TABLE 56—HARDWAR SAND BONDED WITH 5% BIHAR BENTONITE: CRUSHING STRENGTH

PERIOD OF EXPOSURE, <i>hr</i>	CRUSHING STRENGTH <i>lb./sq. in.</i>	PERIOD OF EXPOSURE, <i>hr</i>	CRUSHING STRENGTH <i>lb./sq. in.</i>
0	5.9	3	14.6
0.5	7.8	4	17.6
1	8.8	5	21.5
2	12.6	24	56.0

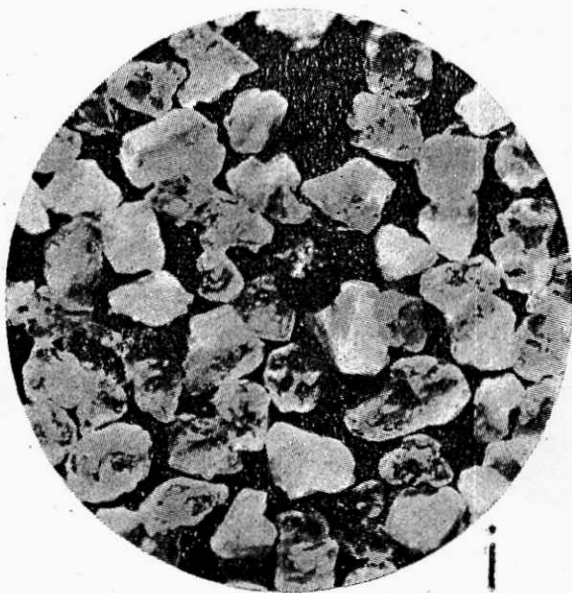
in the specimen tube, the maximum hardness being .87 at 2.4 per cent moisture.

The air setting properties of the sand mixture were studied by exposing the rammed test pieces to the laboratory atmosphere and then determining the compressive strength at regular intervals of exposure (Table 56). After 2 hr exposure, the green strength was nearly doubled and after 24 hr the value was nearly 10 times the original value.

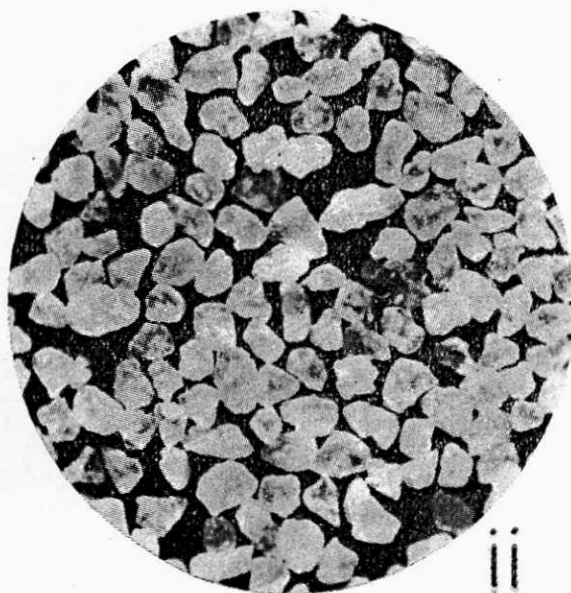
Green and dry moulds of the sand mixture gave satisfactory performance in the casting of cast iron test blocks which were found to have smooth surfaces. A clean shake-out of the castings was obtained from the moulds. The patterns stripped well from the moulds on ramming.

Conclusion. The few castings of simple design which were prepared do not necessarily warrant a conclusive evidence in favour of the sand being definitely suitable for steel foundry practice. This is especially so, when the low refractoriness of the sand resulting from the presence of micaceous and other

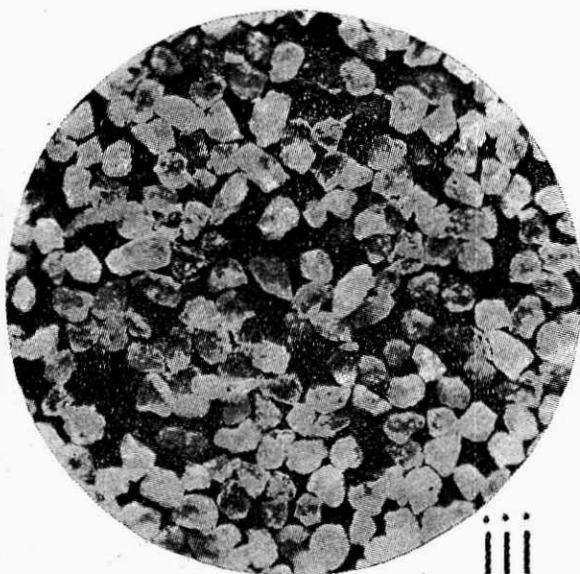
PLATE V



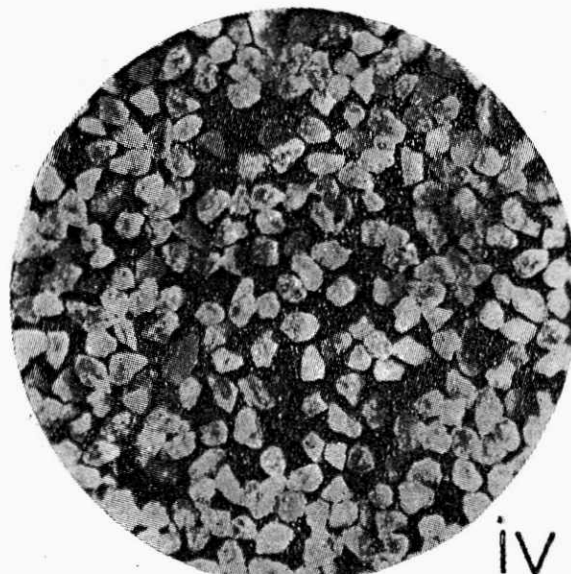
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WASHED SAND GRAINS OF HARDWAR SANDS RETAINED ON (i) 40 MESH ;
(ii) 50 MESH ; (iii) 70 MESH ; AND (iv) 100 MESH ($\times 25$)



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CUMULATIVE PERCENTAGE

impurities is taken into consideration. Washing to remove the fines and flotation to remove mica and ferro-magnesian minerals may improve the refractoriness of the sand.

Brahmani River Sand

Six samples of silica sand collected from different places on the banks of the river Brahmani, in Sundergarh district (Orissa) were received through *Messrs Hindustan Steels Private Ltd, Rourkela*.

Sample BT-9/2. The sand belonged to 'fine' grade and bulk of the grains were subangular to rounded in shape. Sand grains retained to coarser mesh sieves were of composite shape. Size grading and fineness characteristics of the sand are shown in Tables 57(a) & 57(b) and Fig. 12.

Petrological examination showed that the sample was composed mainly of quartz and feldspar; opaque minerals constituted about 4 per cent of the sample and chlorite, about 0.5 per cent, while kyanite and muscovite were present in traces. The results of chemical analysis of the sand are shown in Table 58.

The sample had poor refractoriness, the fusion temperature being 1500°C ., corresponding to Orton Cone 18-19. The sintering range of the sample when bonded with 5 per cent Bihar bentonite was $1250-1350^{\circ}\text{C}$. as determined by Method A and $1200-1250^{\circ}\text{C}$. as determined by Method B. The moulding characteristics of sand bonded with 5 per cent Bihar bentonite

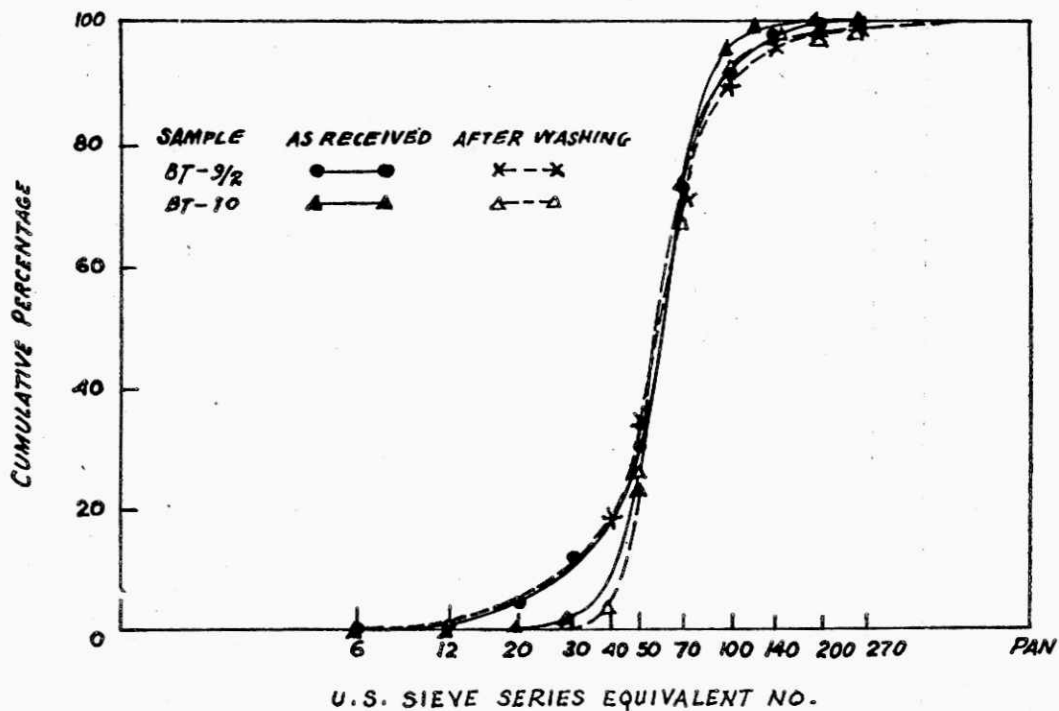


FIG. 12.—BRAHMANI RIVER SAND SAMPLES BT-9/2 AND BT-10: CUMULATIVE GRADING CURVES

TABLE 57(a)—BRAHMANI RIVER SAND: SIZE GRADING

U.S. SIEVE EQUI- VALENT No.	% RETAINED											
	SAMPLE BT-9/2		SAMPLE BT-10		SAMPLE K-5		SAMPLE K-10		SAMPLE S-5		SAMPLE S-10	
	As- received	After washing	As- received	After washing	As- received	After washing	As- received	After washing	As- received	After washing	As- received	After washing
6	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
12	0.3	0.20	Nil	Nil	Nil	0.40	Nil	Nil	0.8	1.50	1.20	0.72
20	4.5	4.42	Nil	Nil	2.6	4.40	1.0	0.92	10.6	8.42	10.4	8.30
30	6.8	6.64	0.10	0.38	14.2	12.22	1.2	1.50	14.0	15.00	14.2	12.54
40	6.2	6.20	2.11	2.28	41.6	38.80	3.0	1.98	23.5	26.42	23.4	22.50
50	17.3	16.22	22.82	20.30	30.4	32.50	11.8	7.02	27.9	28.02	28.4	29.32
70	37.6	37.20	52.10	51.06	8.8	8.44	31.0	24.44	13.6	12.42	13.2	14.42
100	18.8	19.42	18.01	19.48	1.6	1.70	31.8	31.42	5.9	5.08	5.4	7.80
140	6.1	5.60	4.10	4.10	0.6	0.50	15.0	18.84	2.8	2.06	2.6	1.90
200	1.7	3.20	0.70	0.70	Nil	0.20	3.8	6.58	0.5	0.22	0.4	1.00
270	0.3	0.24	0.10	0.26	Nil	0.14	0.6	2.30	Nil	0.20	0.1	0.34
Pan	0.2	0.22	Nil	0.32	Nil	0.10	0.6	1.76	Nil	Nil	Nil	0.54

TABLE 57(b)—BRAHMANI RIVER SAND: FINENESS CHARACTERISTICS

CHARACTERISTIC	SAMPLE BT-9/2			SAMPLE BT-10			SAMPLE K-5			SAMPLE K-10			SAMPLE S-5			SAMPLE S-10		
	As- received	After washing	After washing	As- received	After washing	After washing	As- received	After washing	After washing	As- received	After washing	After washing	As- received	After washing	After washing	As- received	After washing	After washing
Clay, %	—	0.4	—	—	0.50	—	—	0.4	—	—	3.2	—	—	0.22	—	—	—	0.4
Clay class	—	A	—	—	B	—	—	A	—	—	C	—	—	A	—	—	—	A
Grain fineness No.	52.4	53.7	53.7	54.8	54.8	54.8	33.9	28.7	28.7	67.1	78.4	36.6	35.7	35.7	36.3	40.3	40.3	40.3
Grain class No.	5	5	5	5	5	5	7	8	8	5	4	7	7	7	7	5	5	5
Max. retention on sieves, %	79.9	79.4	97.03	94.04	94.04	95	95	91.96	89.6	81.72	79	81.86	79.2	78.8	78.8	78.8	78.8	78.8
Fines, %	2.2	3.66	0.71	1.28	Nil	0.44	5.0	10.64	0.5	0.42	0.5	0.5	0.5	0.5	0.5	1.8	1.8	1.8

TABLE 58—BRAHMANI RIVER SAND: CHEMICAL ANALYSIS

CHEMICAL CONSTITUENT	SAMPLE BT-9/2		SAMPLE BT-10		SAMPLE K-5		SAMPLE K-10		SAMPLE S-5		SAMPLE S-10	
	As- received	After washing	As- received	After washing	As- received	After washing	As- received	After washing	As- received	After washing	As- received	After washing
SiO ₂ , %	82.00	82.30	82.52	82.64	83.4	83.56	77.50	79.56	83.76	84.28	84.84	84.44
Al ₂ O ₃ , %	8.46	9.24	9.83	9.51	7.1	6.90	10.20	9.00	8.28	8.66	6.39	6.71
Fe ₂ O ₃ , %	3.00	3.80	1.28	1.78	2.8	2.32	2.70	2.50	1.80	2.00	2.20	2.60
TiO ₂ , %	0.44	0.56	0.25	0.25	0.50	0.54	0.86	0.78	0.20	0.26	0.206	0.206
CaO, %	1.85	1.88	2.00	2.00	2.90	2.90	3.50	3.30	1.74	1.63	1.73	1.67
MgO, %	0.18	0.13	Trace	Trace	0.41	0.43	0.60	0.57	0.46	0.40	Trace	Trace
Na ₂ O, %	0.90	0.85	0.816	0.97	0.85	0.74	1.50	1.36	0.56	0.53	0.55	0.69
K ₂ O, %	2.01	1.90	2.97	3.02	2.20	2.20	2.80	2.30	2.50	2.40	3.02	3.56
Loss on ignition, %	0.46	0.38	0.50	0.46	0.42	0.48	0.94	0.66	0.38	0.30	0.44	0.44

TABLE 59

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TABLE 59—BRAHMANI RIVER SAND SAMPLE BT-9/2 BONDED WITH 5% BIHAR BENTONITE:
MOULDING CHARACTERISTICS AT DIFFERENT MOISTURE CONTENTS

CHARACTERISTIC	MOISTURE, %					
	1.9	2.5	3.4	3.8	4.5	6.3
Green permeability No.	90	100	125	135	150	140
Green compressive strength, lb./sq. in.	8.6	7.7	5.5	3.8	3.0	2.7
Green shear, lb./sq. in.	2.1	1.8	1.4	1.0	0.7	0.6
Mould hardness No.	85	83	75	69	55	45
Flowability, %	83	82	81	81	81	80
Shatter index	32	25	19	16	7	5
Dry compressive strength, lb./sq. in.	40	49	62	72	80	90
Dry shear, lb./sq. in.	11	13.5	20	22.5	25	30
Bulk density after compression, g./cc.	1.524	1.534	1.544	1.553	1.573	1.582

were susceptible to considerable variations with change in moisture content. Maximum green compressive strength (8.6 lb./sq. in.) was obtained at 1.9 per cent moisture. Green permeability was maximum (150) at 4.5 per cent moisture. The flowability was fairly satisfactory. The shatter index value was maximum (32) at 1.9 per cent moisture. The dry strength was found to steadily increase from 40 lb./sq. in. at 1.9 per cent moisture to 90 lb./sq. in. at 6.3 per cent moisture. The mould hardness varied from 85 to 45, the maximum value being recorded at 1.9 per cent moisture (Table 59).

Castings of cast iron were found to strip easily from the moulds without any sandy layer adhering to the castings.

Sample BT-10. The sample, with subangular to rounded sand grains was found to contain mostly quartz, and feldspar; in addition, 4.5 per cent of opaque minerals and 1.5 per cent of chlorite and biotite were present. The sand grains fused at 1500°C., corresponding to Orton Cone 18-19. The cumulative grading curves of sample BT-10 are shown in Fig. 12.

The sintering range of the sand-bentonite mixture (100:5) was found to be 1250-1350°C. by Method A and 1200-1250°C. by Method B.

The mixture showed maximum green compressive strength (6.1 lb./sq. in.) and green permeability (165) at 1.6 and 5.0 per cent moisture content respectively. The dry strength was maximum (66 lb./sq. in.) at 7 per cent

TABLE 60—BRAHMANI RIVER SAND SAMPLE BT-10 BONDED WITH 5% BIHAR BENTONITE: MOULDING CHARACTERISTICS AT DIFFERENT MOISTURE CONTENTS

CHARACTERISTIC	MOISTURE, %						
	1.6	2.8	3.2	4.0	5.0	6.0	7.0
Green permeability No.	125	145	150	160	165	160	150
Green compressive strength, lb./sq. in.	6.1	4.9	4.5	3.5	3.1	2.0	1.6
Green shear, lb./sq. in.	1.4	1.3	1.2	0.8	0.7	0.7	0.6
Mould hardness No.	80	77	75	69	58	55	54
Flowability, %	84	81	81	81	80	80	80
Shatter index	26.3	22.8	22.0	21.8	21.0	16.5	13.5
Dry compressive strength, lb./sq. in.	20	27	30.0	40.0	60.0	65.5	66.0
Dry shear, lb./sq. in.	3.6	6.2	7.8	16.5	19	20	22.1
Bulk density after compression, g./cc.	1.428	1.446	1.456	1.476	1.505	1.534	1.544

moisture content (Table 60). The optimum moisture range for working the bonded sand appears to be about 3 per cent for green sand moulding and 5 per cent for dry sand practice.

Sample K-5. The sand was of 'medium' grade, the sand grains being mostly subangular to rounded (Fig. 13).

Petrological examination of the sand showed it to consist mostly of quartz and feldspar; opaque minerals (2.5 per cent), chlorite and biotite (2 per cent) and muscovite and kyanite (0.5 per cent) were the other minor mineral constituents. The chemical composition of the sand is shown in Table 58.

The fusion temperature of the sand was found to be 1540°C., corresponding to Orton Cone 20. The sintering range of the sand sample on bonding with Bihar bentonite to the extent of 5 per cent was found to be 1250–1350°C. by Method A and 1250–1300°C. by Method B.

The bonded sand showed higher permeability values than the raw sand; the maximum value of 500 was obtained at 3.2 per cent moisture content. The green and dry compressive strength values were, however, poor. Maximum green strength (5.3 lb./sq. in.) and dry compressive strength (44 lb./sq. in.) were obtained at 1.4 and 4.9 per cent moisture content respectively. The shatter index also was low, the maximum value being 17 at 1.4 per cent moisture content (Table 61).

TABLE

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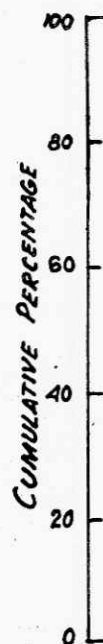
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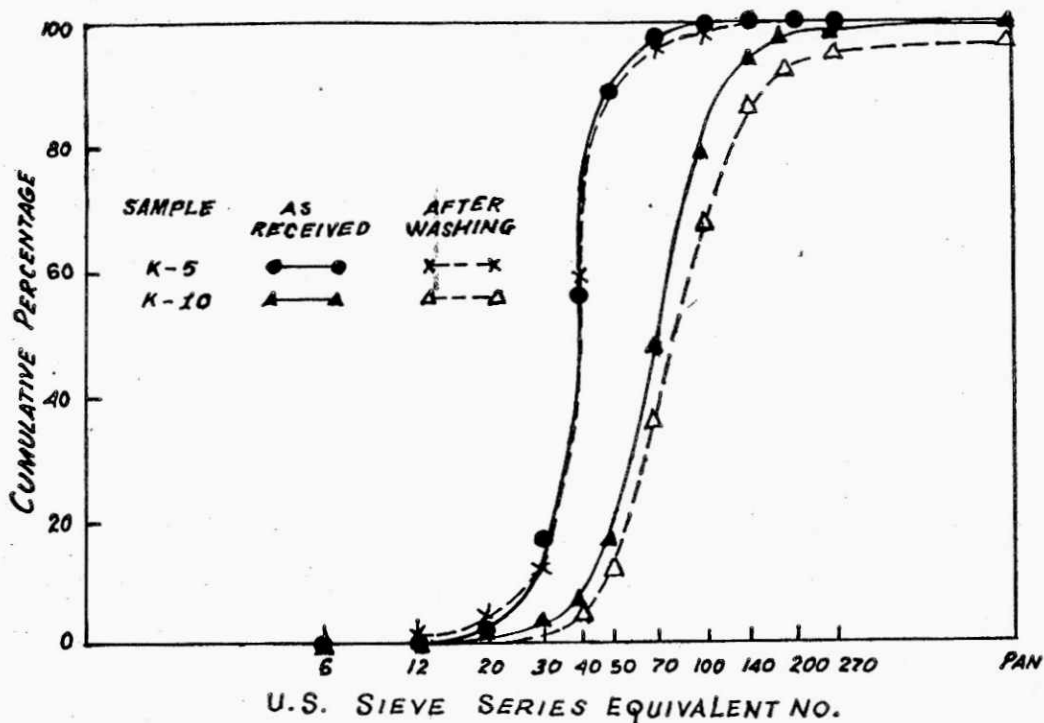
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**TABLE 61—BRAHMANI RIVER SAND SAMPLE K-5 BONDED WITH 3% BIHAR BENTONITE:
MOULDING CHARACTERISTICS AT DIFFERENT MOISTURE CONTENTS**

	MOISTURE, %				
	1.4	2.2	3.2	4.2	4.9
Green permeability No.	450	490	500	490	460
Green compressive strength, lb./sq. in.	5.3	4.0	2.9	2.1	2.1
Green shear, lb./sq. in.	1.4	1.0	0.8	0.7	0.6
Mould hardness No.	79	75	73	70	65
Flowability, %	83	84	84	83	82
Shatter index	17	16	15	14	14
Dry compressive strength, lb./sq. in.	18	28.5	36	37.5	44
Dry shear, lb./sq. in.	5	5.5	6.9	8.4	13
Bulk density after compression, g./cc.	1.456	1.476	1.495	1.515	1.534



**FIG. 13—BRAHMANI RIVER SAND SAMPLES K-5 AND K-10: CUMULATIVE
GRADING CURVES.**

Casting characteristics of the bonded sand studied with cast iron test blocks were satisfactory with respect to surface finish, stripping of the castings, etc.

Sample K-10. This sand was found to be of 'medium fine' grade, with subangular to rounded grains (Fig. 13).

Petrological examination revealed the sand to consist of quartz and feldspar as the major constituents; opaque minerals (2 per cent); chlorite and biotite (2 per cent) and muscovite (1 per cent) were the other minerals present. The chemical composition of the sand is shown in Table 58.

The fusion temperature of the sand was found to be $1500^{\circ}\text{C}.$, corresponding to Orton Cone 18-19. Approximate sintering range of the sand on bonding with Bihar bentonite to the extent of 5 per cent was $1200-1250^{\circ}\text{C}.$

The moulding behaviour of the bonded sand is shown in Table 62.

For the casting of grey iron, the sand was found suitable after bonding with bentonite (5 per cent).

Sample S-5. This sand belonged to 'medium' grade, the washed sand grains being mostly subangular in shape (Fig. 14).

Petrological examination of the sample revealed mainly the presence of quartz and feldspar, with 6 per cent opaque minerals and 3 per cent chlorite; muscovite and biotite were present in traces. The chemical composition of the sand is shown in Table 58.

TABLE 62—BRAHMANI RIVER SAND SAMPLE K-10 BONDED WITH 5% BIHAR BENTONITE: MOULDING CHARACTERISTICS AT DIFFERENT MOISTURE CONTENTS

	MOISTURE, %				
	1.4	2.2	3.0	3.9	5.2
Green permeability No.	100	115	115	110	100
Green compressive strength, lb./sq. in.	9.3	7.5	6.3	5.1	4.6
Green shear, lb./sq. in.	1.6	1.4	1.3	1.1	0.9
Mould hardness No.	85	83	79	76	72
Flowability, %	83	81	80	78	77
Shatter index	34	30	29	28	21
Dry compressive strength, lb./sq. in.	19.5	33	47	55.5	73.5
Dry shear, lb./sq. in.	5.5	9	12	16.5	21.5
Bulk density after compression, g./cc.	1.446	1.467	1.476	1.495	1.524

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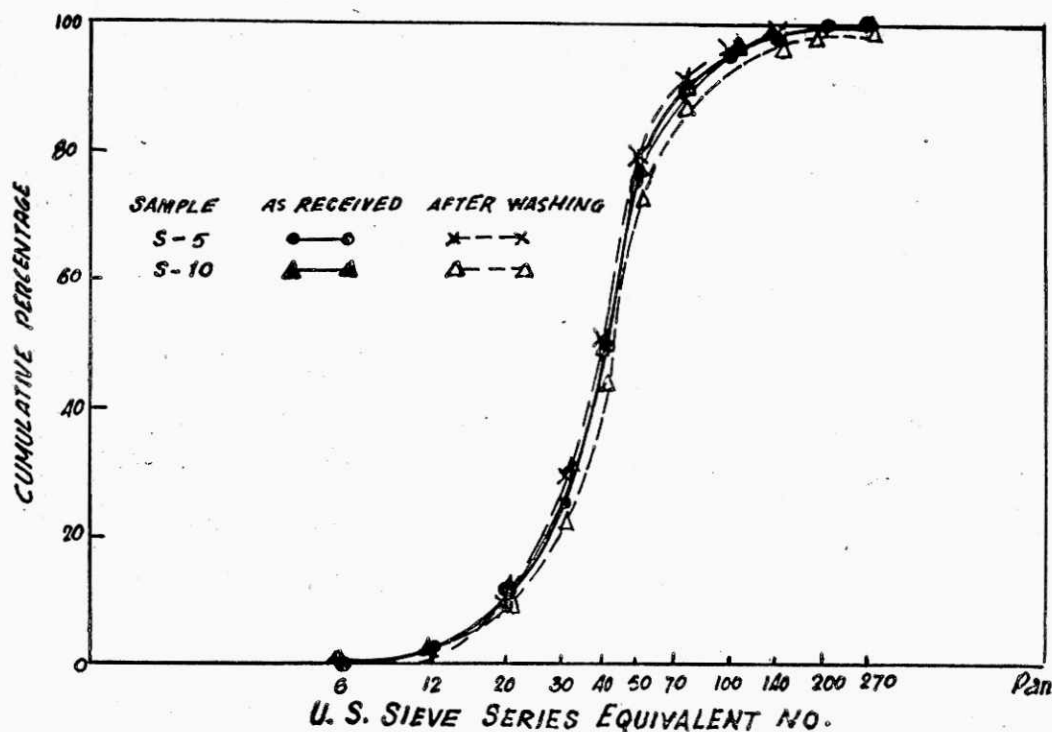


FIG. 14—BRAHMANI RIVER SAND SAMPLES S-5 AND S-10: CUMULATIVE GRADING CURVES

The fusion temperature of the sand was found to be $1595^{\circ}\text{C}.$, corresponding to Orton Cone 26. After bonding with Bihar bentonite to the extent of 5 per cent, the sand sintered in the range 1250 – $1300^{\circ}\text{C}.$ as determined by Method A and 1300 – $1350^{\circ}\text{C}.$ as determined by Method B.

The bonded sand showed maximum permeability (240), mould hardness (35) and green compressive strength (7.9 lb./sq. in.) at 1.9 per cent moisture content. Maximum dry compressive strength (86 lb./sq. in.) and shatter index (16) were obtained at 6.2 and 1.9 per cent moisture respectively (Table 63).

The casting characteristics of the bonded sand with respect to cast iron was fairly satisfactory.

Sample S-10. This sand belonged to 'medium' grade and the sand grains were mostly subangular in shape. The size grading and fineness characteristics of the sand are shown in Tables 57(a) & 57(b) and Fig. 14.

The sand had the following mineralogical composition: Quartz, 65; feldspar, 25; opaque minerals, 5.5; muscovite and kyanite, 2.5; and chlorite and biotite, 1.5 per cent. The results of chemical analysis of the sand as received and after washing are presented in Table 58.

The refractoriness of this sample was slightly higher than that of the other samples of Brahmani river sands investigated, the fusion temperature being $1610^{\circ}\text{C}.$, corresponding to Orton Cone 27–28.

**TABLE 63—BRAHMANI RIVER SAND SAMPLE S-5 BONDED WITH 5% BIHAR BENTONITE:
MOULDING CHARACTERISTICS AT DIFFERENT MOISTURE CONTENTS**

	MOISTURE, %						
	1.9	2.8	3.8	4.2	4.6	5.6	6.2
Green permeability No.	240	240	230	225	220	220	220
Green compressive strength, lb./sq. in.	7.9	6.0	3.8	3.2	2.9	2.4	1.9
Green shear, lb./sq. in.	1.4	0.9	0.7	0.6	0.6	0.6	0.5
Mould hardness No.	75	75	68	66	65	62	58
Flowability, %	79	80	80	80	80	81	81
Shatter index	16	15	15	14	14	13	11
Dry compressive strength, lb./sq. in.	31	42	43	68.5	66.5	76	86
Dry shear, lb./sq. in.	4.2	8	11	17	18	22	24.5
Bulk density after compression, g./cc.	1.524	1.563	1.573	1.582	1.592	1.603	1.612

**TABLE 64—BRAHMANI RIVER SAND S-10 BONDED WITH 5% BIHAR BENTONITE:
MOULDING CHARACTERISTICS AT DIFFERENT MOISTURE CONTENTS**

	MOISTURE, %				
	1.4	2.4	2.9	3.8	5.3
Green permeability No.	300	310	310	310	300
Green compressive strength, lb./sq. in.	5.4	4.5	3.5	3.2	2.5
Green shear, lb./sq. in.	1.4	1.1	0.9	0.8	0.6
Mould hardness No.	75	72	72	70	69
Flowability, %	81	80	79	79	79
Shatter index	17	16	16	15	14
Dry compressive strength, lb./sq. in.	15.5	30	37	56	75
Dry shear, lb./sq. in.	4	8	10	15	18
Bulk density after compression, g./cc.	1.467	1.495	1.515	1.544	1.573

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After bonding with Bihar bentonite (5 per cent), the sand grains sintered at 1250–1350°C. as determined by Method A and 1300–1350°C. as determined by Method B.

The green permeability of the bonded sand remained more or less steady (300–310) over the moisture range 1.4–5.3 per cent. The green compressive strength was maximum (5.4 lb./sq. in.) at 1.4 per cent moisture content. The shatter index values were low throughout the moisture range studied. The dry strength was maximum (75 lb./sq. in.) at 5.3 per cent moisture content (Table 64).

The bonded sand was found to be fairly satisfactory for the casting of iron.

Conclusion. In view of their low silica content and the consequent lowering of the fusion point and sintering temperature, they cannot be recommended for medium and heavy steel castings ; after addition of suitable binders, they might be employed for very light steel castings. In view of the proximity of these deposits to the Rourkela steel plant, upgrading of these sands by suitable ore dressing methods so as to increase their silica content and reduce the content of low melting constituents and thereby improve their refractoriness may be attempted for making them suitable for steel castings.

Gidni Sand

The sand sample, obtained from the river bed near Gidni in Midnapur district (West Bengal), was received through *A. K. Roy*, Calcutta. Since

TABLE 65(a)—GIDNI SAND: SIZE GRADING

U.S. SIEVE EQUIVALENT No.	% RETAINED	
	As-received	After washing
6	Nil	Nil
12	10.27	9.60
20	30.30	27.70
30	21.0	17.90
40	20.25	19.20
50	11.65	12.0
70	3.30	3.70
100	1.10	1.20
140	0.55	0.60
200	0.30	0.40
270	0.15	0.34
Pan	0.37	1.20

it contained considerable amount of gritty material it was first sieved through 6 mesh sieve and the portion passing through the sieve taken up for investigation.

The sand was found to be well graded and belonged to 'medium coarse' grade with very little fines content. The mechanical size grading and fineness characteristics of the sand are shown in Tables 65(a) & 65(b). Cumulative grading curves for the raw and washed sand are shown in Fig. 15.

The sand grains were mostly angular to subangular in shape. Most of the grains were coated with clayey or limonite matter. The results of chemical analysis of the raw and washed sand are presented in Table 66.

TABLE 65(b)—GIDNI SAND: FINENESS CHARACTERISTICS

	AS-RECEIVED	AFTER WASHING
Clay, %	—	5.70
Clay class	—	B 1
Grain fineness No.	23.45	27.19
Max. retention on 20, 30 and 40 mesh sieves, %	71.55	64.80
Fines, %	0.82	1.94

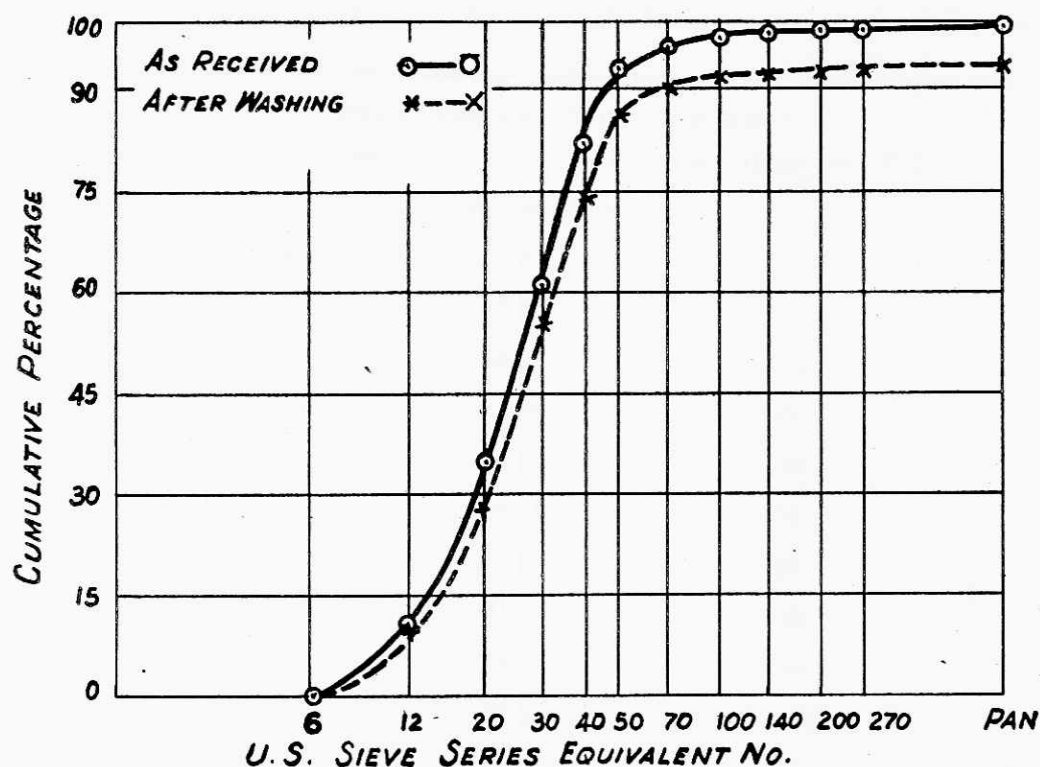


FIG. 15—GIDNI SAND: CUMULATIVE GRADING CURVES

TABLE 66—GIDNI SAND: CHEMICAL ANALYSIS

CHEMICAL CONSTITUENT	AS-RECEIVED	AFTER WASHING
SiO ₂ , %	82.48	84.08
Fe ₂ O ₃ , %	2.70	1.96
Al ₂ O ₃ , %	5.98	5.38
TiO ₂ , %	1.92	1.82
CaO, %	1.54	1.65
MgO, %	0.40	0.36
Na ₂ O, %	0.83	1.12
K ₂ O, %	2.21	2.27
Loss on ignition, %	1.46	0.76

TABLE 67—GIDNI SAND: HIGH TEMPERATURE CHARACTERISTICS

(Soaking period, 1.5 hr)

FIRING TEMP. °C.	CHARACTERISTICS OF TEST PIECES AFTER FIRING
1050	Brick red colour; collapsed when touched by hand
1150	Reddish brown colour; test pieces formed a compact mass, surfaces friable
1250	Test pieces formed a hard compact mass, no surface friability; change in volume and shape

TABLE 68—GIDNI SAND BONDED WITH 5% ASIATIC MINERALS BENTONITE:
MOULDING CHARACTERISTICS AT DIFFERENT MOISTURE CONTENTS

	MOISTURE, %				
	1.6	2.2	2.7	3.1	4.3
Green permeability No.	155	235	175	235	225
Green compressive strength, lb./sq. in.	19	16.5	11.25	11.0	9.7
Green shear, lb./sq. in.	4.5	3.9	3.2	3.1	2.4
Mould hardness No.	88	87	85	87	83
Flowability, %	77	73.5	74	68	68
Dry compressive strength, lb./sq. in.	39.7	55.7	59.5	90.0	136.5
Dry shear strength, lb./sq. in.	7.2	11.5	14.0	22.2	27.25
Bulk density after compression, g./cc.	1.603	1.613	1.622	1.642	1.661

Petrological examination showed the presence of 69 per cent quartz and 8 per cent feldspar. Other minerals present were: mica, 7 per cent; hornblende, 6 per cent; and opaque minerals, e.g. magnetite and limonite, 4 per cent. Most of the mineral constituents were found to be coated with clayey matter.

Sintering range of the sand grains was found to be quite low between 1150–1200°C. (Table 67).

The sand exhibited maximum green permeability (275) and green compressive strength (19 lb./sq. in.) at 2.7 and 1.6 per cent moisture content respectively. The optimum moisture range for working the sand was found to be 2.4–3.4 per cent (Table 68).

Green and dry sand moulds of the sand did not give satisfactory service for grey iron castings. However, with the application of a suitable dressing, the moulds may be suitable for steel casting.

Adjoy River Sand

The sand sample, belonging to 'medium fine' grade was received through *Messrs Samla Collieries Ltd*, Pandaveshwar. It was collected from the bed of Adjoy river in Burdwan district (West Bengal). As received, it was pale brown in colour. The size grading and fineness characteristics of the sand are shown in Tables 69(a) & 69(b). Cumulative grading curves for the raw and washed sands are shown in Fig. 16.

TABLE 69(a)—ADJOY RIVER SAND: SIZE GRADING

U.S. SIEVE EQUIVALENT No.	% RETAINED	
	As-received	After washing
6	Nil	Nil
12	Nil	Nil
20	1.10	2.60
30	5.10	9.00
40	15.80	22.40
50	21.10	22.40
70	17.70	14.80
100	24.25	17.60
140	11.10	7.00
200	2.60	1.60
270	0.60	0.20
Pan	0.50	0.40

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TABLE 69(b)—ADJOY RIVER SAND: FINENESS CHARACTERISTICS

	AS-RECEIVED	AFTER WASHING
Clay, %	—	1.4
Clay class	—	B
Grain fineness No.	57.6	48.6
Grain class No.	5	6
Max. retention on 40, 50, 70 and 100 mesh sieves, %	78.85	77.20
Fines, %	3.7	2.2

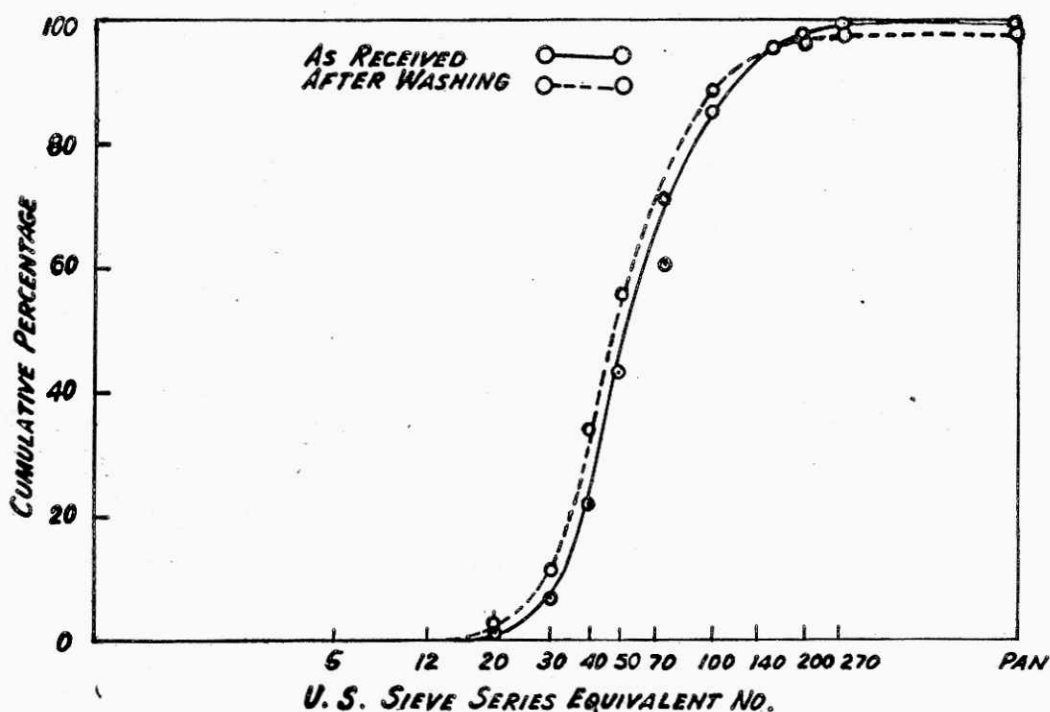


FIG. 16—ADJOY RIVER SAND: CUMULATIVE GRADING CURVES

Petrological examination of the sand showed it to contain quartz as the predominant mineral constituent; amphiboles were present to the extent of about 5 per cent. Other minerals present in small amounts were garnet, magnetite, zircon, epidote, mica and feldspar.

The sand grains were mostly subangular to rounded, the latter predominating on finer meshes (Plate VI).

The results of chemical analysis of the sand are shown in Table 70.

The sample showed poor refractoriness, the fusion temperature being 1430°C.

Standard test pieces (2 in. × 2 in.) fired at different temperatures in the range 1150–1450°C. showed an overall decrease in volume ; the test specimens were considerably distorted. Vitrification of the grains was observed in the case of test pieces fired at 1250°C. (Table 71). After bonding with Bihar bentonite to the extent of 5 per cent, the sand sintered in the range 1200–1250°C.

Moulding characteristics of the bonded sand are shown in Table 72. Maximum green compressive strength (6.4 lb./sq. in.) and green strength (2.4 lb./sq. in.) were obtained at 2.2 and 6.2 per cent moisture respectively. The

TABLE 70—ADJOY RIVER SAND: CHEMICAL ANALYSIS

CHEMICAL CONSTITUENT	AS-RECEIVED	AFTER WASHING
SiO ₂ , %	81.18	82.12
Al ₂ O ₃ , %	9.48	9.82
Fe ₂ O ₃ , %	2.10	1.90
TiO ₂ , %	0.24	0.20
CaO, %	1.98	2.08
MgO, %	0.54	0.35
Na ₂ O, %	0.75	0.75
K ₂ O, %	2.11	1.62
Loss on ignition, %	0.74	0.42

TABLE 71—ADJOY RIVER SAND BONDED WITH 5% BIHAR BENTONITE:
HIGH TEMPERATURE CHARACTERISTICS

FIRING TEMP. °C.	CHARACTERISTICS OF TEST PIECES AFTER FIRING
1150	Reddish-brown colour; test pieces crumbled to powder on cooling to room temperature
1250	Sintering of grains, test pieces turned into compact mass
1350	Brownish-grey colour; considerable shrinkage with slight deformation in shape; a low metallic sound when struck
1450	Dark-grey colour; surfaces very hard and glossy; sintering of grains; test pieces completely deformed and deshaped; considerable reduction in size; clear metallic sound when struck

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TABLE 72—ADJOY RIVER SAND BONDED WITH 5% BIHAR BENTONITE:
MOULDING CHARACTERISTICS AT DIFFERENT MOISTURE CONTENTS

	MOISTURE, %			
	2.2	3.0	4.0	6.2
Green permeability No.	155	153	150	130
Green compressive strength, lb./sq. in.	6.4	6.0	4.0	2.4
Green shear, lb./sq. in.	1.6	1.3	0.8	0.4
Mould hardness No.	80	78	77	75
Flowability, %	75	75	76	80
Dry compressive strength, lb./sq. in.	40	45	54	70
Dry shear, lb./sq. in.	5.5	8.0	11.0	20.0
Bulk density after compression, g./cc.	1.505	1.524	1.553	1.573

permeability was on the whole satisfactory, the maximum value being 155 at 2.2 per cent moisture content. The flowability was fairly satisfactory. The dry strength steadily increased from 40 lb./sq. in. at 2.2 per cent moisture to 70 lb./sq. in. at 6.2 per cent moisture. The mixture rammed hard in the specimen tube, showing maximum hardness (80) at 2.2 per cent moisture content.

Cast iron test blocks prepared in green and dry sand moulds had fairly good surface characteristics. A clean shake out of the castings was obtained from the moulds.

Conclusion. In view of its low silica content and poor refractoriness, the sand is unsuitable for steel moulding both by green and dry sand practices. After bonding with bentonite to the extent of 5 per cent, it is suitable for grey iron castings.

Mogra Sand

This sand was obtained from Baghaidar (Pandua), Hooghly district (West Bengal). It contained 0.22 per cent clay grade matter, and assayed about 85 per cent silica, 9 per cent alumina, 1 per cent lime, 1 per cent magnesia, and 2 per cent alkalis. The grains were mostly subangular in shape and were composed principally of quartz. Bulk of the sand grade was retained on 40 and 50 mesh sieves. The refractoriness of the sample was fairly satisfactory, the fusion point being 1450°C.

Conclusion. The sand can be used for iron and non-ferrous castings, admixture with finer grade sand is desirable for light castings where surface finish is important.

Yadgiri Silica Sand

The sand, collected from Yadgiri, about 400 miles from Hyderabad, was supplied by *Messrs Ruston and Hornsby (India) Private Ltd*, Poona. It was of 'medium' to 'fine' grade, the sand grains being mostly subangular in shape. The size grading and fineness characteristics are shown in Tables 73(a) & 73(b). Cumulative grading curves are shown in Fig. 17.

Results of chemical analysis of the raw and washed sand are shown in Table 74. Petrological examination of the sand showed it to have the following mineralogical composition: Quartz, 51 ; feldspar, 45 ; hypersthene, 3 ; and sphene, apatite, muscovite and iron oxide, 1 per cent.

TABLE 73(a)—YADGIRI SAND: SIZE GRADING

U. S. SIEVE EQUIVALENT No.	% RETAINED	
	As-received	After washing
6	Nil	Nil
12	Nil	Nil
20	0.03	0.02
30	0.05	0.04
40	1.33	0.48
50	23.36	17.18
70	26.41	26.30
100	21.65	22.72
140	16.64	18.02
200	6.72	7.64
270	2.52	2.76
Pan	1.63	2.12

TABLE 73(b)—YADGIRI SAND: FINENESS CHARACTERISTICS

	AS-RECEIVED	AFTER WASHING
Clay, %	—	3.2
Clay class	—	C
Grain fineness No.	73.68	78.44
Grain class	4	4
Max. retention on 50, 70, 100 and 140 mesh sieves, %	87.46	84.22
Fines, % _q	10.87	11.92

TABLE 74—YADGIRI SAND: CHEMICAL ANALYSIS

CHEMICAL CONSTITUENT	AS-RECEIVED	AFTER WASHING
SiO ₂ , %	77.5	78.8
Al ₂ O ₃ , %	12.37	11.98
Fe ₂ O ₃ , %	0.56	0.58
TiO ₂ , %	0.17	0.18
CaO, %	1.25	1.35
MgO, %	0.72	0.63
Na ₂ O + K ₂ O, %	6.51	5.62
Loss on ignition, %	0.92	0.86

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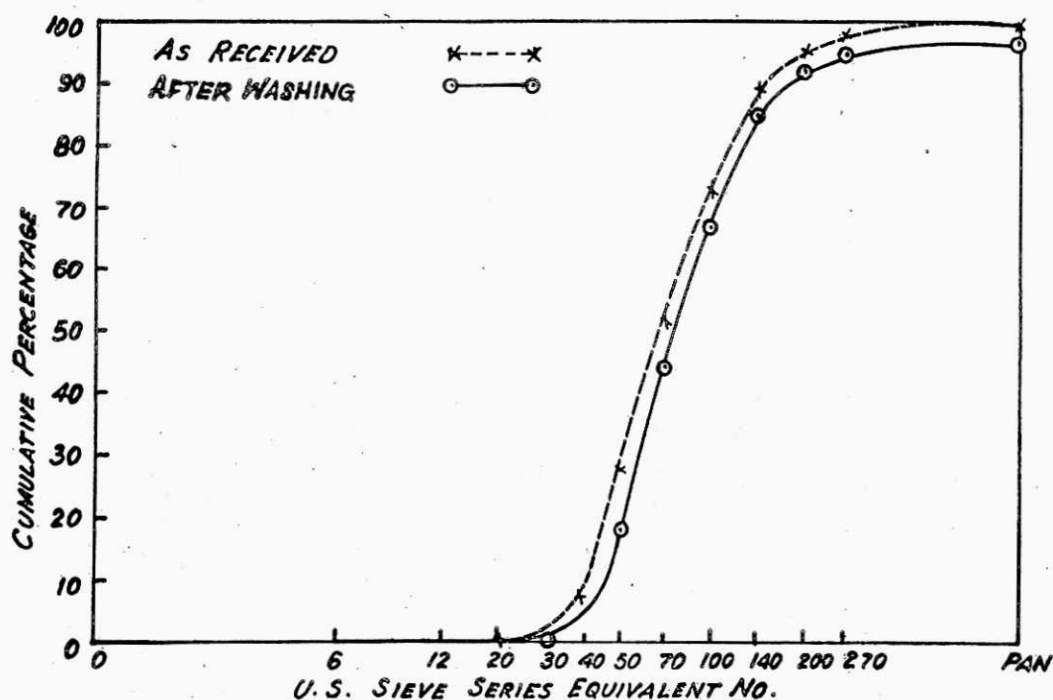


FIG. 17—YADGIRI SILICA SAND: CUMULATIVE GRADING CURVES

TABLE 75—YADGIRI SAND BONDED WITH 5% BIHAR BENTONITE: HIGH TEMPERATURE CHARACTERISTICS

(Initial vol. of test pieces, 6.284 cu. in.; soaking period, 1.5 hr)

FIRING TEMP. °C.	VOL. AFTER FIRING cu. in.	SURFACE CHARACTERISTICS OF TEST PIECES AFTER FIRING
950	6.3	Orange colour, friable; crumbled to powder on touching
1000	6.3	do.
1050	6.3	do.
1100	6.2	Light orange colour, less friable
1150	5.2	Light grey colour; surface very hard; test pieces deformed and deshaped

The sintering range of the sand grains was found to be 1100–1150°C. Results of high temperature tests are shown in Table 75.

Two synthetic moulding sand compositions were studied. Mixture 1 was prepared by mixing 5 per cent Bihar bentonite with the sand. In Mixture 2, in addition to 5 per cent Bihar bentonite, 2 per cent dextrine was added. Moulding characteristics of the two mixtures are given in Tables 76 & 77.

In the case of Mixture 1, permeability increased gradually from 110 at 0.9 per cent moisture to 180 at 2 per cent moisture, then remained constant up

TABLE 76.—YADGIRI SAND BONDED WITH 5% BIHAR BENTONITE: MOULDING CHARACTERISTICS AT DIFFERENT MOISTURE CONTENTS

	MOISTURE, %									
	0.9	1.3	1.4	2.05	2.5	2.8	2.9	3.3	3.8	5.3
Green permeability No.	112	131	130	180	180	180	177	172	162	140
Green compressive strength, lb./sq. in.	8.6	10.45	11.75	7.85	6.75	6.3	6.2	5.6	4.65	3.2
Green shear, lb./sq. in.	1.4	2	2.15	1.65	1.7	1.5	1.27	1.1	1.1	0.6
Mould hardness No.	84	87	88	85	85	81	78	80	78	72
Flowability, %	86	82.5	80	77	78	78	77	77	78	79
Shatter index	15	32.5	50.3	50.3	49.3	50.6	62.6	45.6	49.7	37.1
Dry compressive strength, lb./sq. in.	2	3.8	15.5	21	32.5	38.5	33	33	41.5	62
Dry shear, lb./sq. in.	0.5	1	3.5	7	8.25	7.7	7	6.5	8.7	12
Bulk density after compression, g./cc.	1.49	1.45	1.44	1.42	1.43	1.43	1.45	1.45	1.48	1.52

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TABLE 77—YADGIRI SAND BONDED WITH 5% BENTONITE AND 2% DEXTRINE:
MOULDING CHARACTERISTICS AT DIFFERENT MOISTURE CONTENTS

	MOISTURE, %					
	1.4	1.85	2.7	3.25	4.85	5.9
Green permeability No.	207	190	195	185	133	125
Green compressive strength, lb./sq. in.	10.1	9.7	8.45	7.6	4.7	3.9
Green shear strength, lb./sq. in.	2.5	2.4	2.1	1.85	1.3	1
Mould hardness No.	85	84	82	82	74	67
Flowability, %	74	67.5	69.5	68.5	74	76
Shatter index	80.1	86.8	89.1	88.6	76	62.7
Dry compressive strength, lb./sq. in.	26.5	51.3	69	66	168	165
Dry shear, lb./sq. in.	6.85	11	20	23	35.5	38.5
Bulk density after compression, g./cc.	1.36	1.36	1.4	1.43	1.5	1.53

to 2.8 per cent moisture and decreased thereafter. Similarly, green compressive strength increased gradually at first, from 8.5 lb./sq. in. at 0.9 per cent moisture to 11.75 lb./sq. in. at 1.4 per cent moisture; there was a gradual fall with further increase in moisture content. The green shear strength showed a similar trend, the maximum value being 2.1 lb./sq. in. at 1.4 per cent moisture. Flowability decreased from 86 at 0.9 per cent moisture to 77 at 2 per cent moisture and then remained almost constant with further addition of moisture.

In the case of Mixture 2, maximum permeability (207) was obtained at 1.4 per cent moisture. Green compressive strength was maximum (10.1) at the lowest moisture content (1.4 per cent), falling with increase in moisture content. The green shear strength was maximum (2.5) at 1.4 per cent moisture.

Casting characteristics of Mixtures 1 and 2 were studied by casting standard (3 in. × 3 in. × 3 in.) brass and cast iron blocks in green and dry moulds. The surface characteristics of the brass test pieces were found to be satisfactory, but in the case of cast iron, sand fused on to the surfaces. This may be attributed to the low sintering range of the sand, probably resulting from its high feldspar content.

Conclusion. The sand cannot be considered suitable even for grey iron foundry jobs, unless mixed with a high silica sand of a more open type on account of its low permeability, dry strength and refractoriness of the bonded sand. It may, however, be good enough for non-ferrous castings.