Gilsonite as a Carbonaceous Foundry Sand Additive

ABSTRACT

Laboratory tests were performed to determine the effect of five commonly used carbonaceous additives on new sand mixes. The additives evaluated were seacoal, pitch, petroleum asphalt, Gilsonite of a "coarse" and "fine" grind, and blown asphalt. The tests comprised evaluating physical properties of new sand mixes at approximately 1% volatile at 900°F (482.2°C) and 40% compactability.

Physical sand properties developed with non-seacoal carbonaceous materials were equal to or superior to seacoal at significantly lower additive levels. Gilsonite and asphalt mixes appeared to improve physical properties of density, water requirements and green, dry, baked and hot strengths. An even greater improvement in foundry sand green, baked, and hot strength was obtained by increasing the fineness of grind of the Gilsonite. It is postulated the finer material provides better sand coating. The higher strength may be attributed to improved sand wetting by the thermoplastic asphalt materials.

The gas evolution curve indicated Gilsonite and asphalt reacted more rapidly than seacoal but had far less total gas volume. Gilsonite and asphalt at one third the level of seacoal had the same total volatiles at one third the seacoal additive level.

A foundry research study showed casting finish with Gilsonite was equal to seacoal and better than most other substitutes. Another study with system sand confirmed the laboratory results of this research on new sand mixes with respect to sand properties and casting finish.

INTRODUCTION

Through the years there has been extensive research and many technical papers written on carbonaceous additives used in foundry molding sands. The majority of this research and publication concerned the effect of various carbonaceous materials on casting quality, gas evolution rates, lustrous carbon(1), clay activity and volatile composition.

It was the object of this research to compare the effect of several commonly used carbonaceous materials on foundry sand properties. This data was compared to available information on system sand performance with respect to properties and casting finish.

EXPERIMENTAL PROCEDURE

Five foundry grade carbonaceous sand additives were evaluated. They were:

A) Seacoal (ground, dustless, bituminous coal).

B) Pitch (coal tar pitch).

C) Petroleum asphalt (weathered residue from petroleum cracking towers).

D) Gilsonite (natural U.S. asphaltite).

E) Blown asphalt (air-purged asphalt).

The dry and wet-screen analysis of each of these carbonaceous materials is shown in Table I. Two Gilsonite products of different AFS fineness numbers were evaluated in this program. The finer material is typical of that marketed by AGC.

Screen Analysis

Table I

Screen Mesh	Seacoal	Pitch	Pet. Asphalt	Gilsonite	Blown Asphalt							
							Coarse	Fine				
% Retained	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
30	5.7	5.7	30	--	--	--	--	--	--	--	--	--
50	19.9	18.9	3.0	2.8	--	0.1	4.2	4.0	--	--	--	--
70	13.1	11.4	2.8	2.8	0.1	--	9.6	9.2	0.3	--	0.2	0.2
100	12.1	10.2	9.8	9.0	3.8	1.4	19.6	15.6	0.4	0.4	21.3	19.0
200	21.5	19.3	28.0	18.0	28.0	11.7	42.0	22.0	11.6	9.8	39.4	37.3
270	13.5	5.7	23.2	13.4	50.6	7.9	15.0	17.6	39.4	9.5	25.3	10.7
Pan	14.2	28.8	33.2	54.0	17.5	79.0	9.6	31.6	48.3	80.3	13.8	32.8
AFS Fineness	122	145	196	223	196	271	137	178	241	274	162	185

Experience has shown that some carbonaceous materials develop a static charge in screening. Thus, it is felt the wet-screening method is more representative of the particle size distribution for additives used in this study. Both wet and dry screens results are reported.

The ash, sulfur and fixed carbon content of each carbonaceous material are shown in Table II. Studies have shown variation in ash content. The ash values in Table II are typical of the present day quality of carbonaceous materials used in this study.

Ash and Sulfur Contents of Additives

Table II

	Seacoal	Pitch	Petroleum Asphalt	Gilsonite	Blown Asphalt	
Ash, %	7.7	0.2		1.6	2.1	0.1
Sulfur, %	1.0	0.19		1.96	0.27	1.41
Fixed Carbon, %	59.2	68.5		42.5	27.7	34.0

All mixes used in this work contained a washed Lake Michigan subangular, three screen 55 AFS sand. All mixes contained 7% Western bentonite (sodium). Mix #1 contained only Western bentonite. The other mixes contained bentonite plus a carbonaceous additive. Carbonaceous material was added to approximately achieve a 1% volatile level (one hour at 900°F (482°C). In the U.S. many ferrous foundrymen have found this test to be the most interpretive for evaluating molding sand peel and finish.

Each 10,000 gm mix was mixed in a 24" laboratory muller for 10 minutes. Temper water was added to achieve a compactability of approximately 40%.

DISCUSSION AND RESULTS

Table III shows green sand properties of all mixes. All mixes containing an additive required higher water content to achieve the same compactability. This would be expected as there is more surface area to coat. Mixes 4, 5, 6, and 7 required the least water because asphaltic materials do not absorb moisture. The moisture content of seacoal mixes would be even greater than with Gilsonite or asphalt in system sands because of the lower ash and residuals in asphaltic materials.(2)

Green Sand Properties

Table III

Sand Mix No.	1	2	3	4	5	6	7
Additive	Blank	4.5% Seacoal	4.0% Pitch	1.5% Pet. Asphalt	1.5% Gilsonite Fine	1.5% Blown Asphalt Coarse	

Sand Properties

Compactability	41.5	41.5	41.1	40.0	41.2	41.9	40.3
%	2.4	2.65	2.68	2.6	2.6	2.5	2.5
Moisture %	96.1	96.0	98.6	98.5	98.2	96.8	96.5
Density-	1539	1538	1579	1578	1573	--	1546
Lbs/Cu/Ft	158.5	158.0	163.3	163.3	162.4	159.9	159.7
	161	118	97	116	123	127	132
	22.1	23.7	26.0	24.5	25.4	24.2	24.3
	15.2	16.3	17.9	16.9	17.5	16.7	16.8
	1.20	1.42	1.38	1.35	1.41	1.35	1.32
	4.31	4.07	4.64	4.36	4.74	4.36	4.32
	3.0	2.8	3.2	3.0	3.3	--	3.0
	1.07	13.3	8.8	11.9	8.9	12.2	13.0
	36.0	36.0	35.5	36.0	35.5	35.5	35.5
kg/m³							
Spec. Wt.-Gms							
Permeability							
Green Comp.- psi							
N/cm²							
Green Deform- %							
Splitting Str.- psi							
N/cm²							
Friability-%							
Methylene Blue Clay-ML							

The density and specimen weight of the pitch and asphaltic mixes were higher than the seacoal mix. This indicates improved sand flowability due to better surface lubrication. The increase in specimen weight confirms the work done by the AFS Committee 80-A.(2) These research results have been verified in foundry applications with the obvious benefit of closer casting dimensional tolerance and consistent casting weight.

Green compression strength and splitting strength on mixes 3, 4, 5, 6, and 7 were higher than seacoal due to increased density. The presence of + 50 mesh particles in the less finely ground Gilsonite in mix 5 resulted in lower compression and splitting strength than the mix with finer Gilsonite. Pitch and finely ground Gilsonite exhibited the highest green strength. The importance of particle size distribution is readily discernible in this data.

Friability(3) is an indication of a rammed sand's ability to hold edges. Lower values indicate a greater resistance to abrasion. Pitch and finely ground Gilsonite mixes were lowest in friability, indicating improved sand bonding by these additives. The higher AFS fineness Gilsonite provides improved sand bonding, probably due to better binder distribution in the mix. All other mixes have lower but similar friability values.

Table IV contains data on dry and baked compression of the test mixes. These results show that dry compression was increased by the addition of carbonaceous additives to the base sand-bentonite mix. Mix 3, pitch, showed the highest dry strength and mix 5, containing the finely ground Gilsonite, had the second highest strength. Mix 6, which had the coarser Gilsonite in the blend, showed lower dry and baked compression.

Dry Properties

Table IV

Mix No.		1	2	3	4	5	6	7
		Blank	4.5% Seacoal	4.0% Pitch	1.5% Pet. Asphalt	1.5% Gilsonite	1.5% Blown Asphalt	FineCoarse
Dry Compression at 225°F (197.2°C)	psi	61	72	101	72	94	66	73
	N/cm²	42.1	49.6	69.6	47.6	64.8	45.5	50.3
Baked Compression at 400°F (204.4°C)	psi	57	68	198	89	117	74	78
	N/cm²	39.3	46.9	136.5	61.4	80.7	51.0	53.8

Table V contains data on the hot compressive strength of the various mixes. Mixes 4, 5, and 7 show that the asphalts had similar hot strengths peaking at 1650°F (899°C). Mix 1 containing bentonite only peaked at 1800°F (982.2°C) and mixes 2 and 3 containing seacoal and pitch respectively peaked at 1500°F (815.5°C). This indicates that the asphalts and Gilsonite have higher hot strength than seacoal or pitch. Finely pulverized Gilsonite provides the highest hot strength of all mixes. The high dry, baked and hot strengths achieved with Gilsonite have been confirmed in the field with the production of ingot mold and heavy machine tool castings. It is interesting to note that, in spite of lower fixed carbon, hot strength of fine Gilsonite is higher than the other additives. This effect is probably due to better wetting of the silica particles by Gilsonite.

Hot Strength

Table V
psi

Mix No.	1 Blank	2 4.5% Seacoal	3 4.0% Pitch	4 1.5% Pet. Asphalt	5 1.5% Gilsonite Fine	6 1.5% Blown Asphalt Coarse	7
Temperature °F							
500	51	64	81	50	50	42	43
1000	93	90	252	122	100	91	110
1500	272	529	691	409	418	320	225
1650	493	271	651	--	801	662	--
1800	532	134	270	308	276	222	264
2000	146	29	47	140	130	114	124
2250	9	--	8	10	10	10	10

N/cm²

Temperature °C							
260.0	35.2	44.1	55.8	34.5	34.5	29.0	29.6
537.7	64.1	62.1	173.8	84.1	68.9	62.7	75.8
815.5	187.5	364.7	476.4	282.0	288.2	220.6	155.1
898.9	339.9	186.9	448.9	--	522.3	456.4	--
982.2	366.8	92.4	186.1	212.4	190.3	153.0	182.0
1010.0	100.7	20.0	32.4	96.5	89.7	78.6	85.5
1232.2	6.2	--	5.5	6.9	6.9	6.9	6.9

The volatiles and loss on ignition (combustibles) are shown in Table VI. The 900°F (482.2°C) volatiles for all the additives were comparable. The loss on ignition or combustible, showed similar comparable amounts for the three asphaltic materials. The seacoal and pitch mixes had the highest loss on ignition. This was expected as these two mixes contained the highest amount of carbonaceous material. It is interesting to observe that mix 1, containing only bentonite, still had over 0.5% loss on ignition. This verifies the presence of water crystallization in bentonite.(6)

Volatiles, Loss on Ignition, and Gasification Rate of Test Mixes

Gas evolution was determined on equipment developed by H. W. Dietert Company and designed such that all interior surfaces are kept above 230°F (110°C) so that the amount of gas evolved includes water vapor.(7)Table VI shows the seacoal mix evolves gas slower initially, but generates a far greater volume of gas than mixes 3, 4, 5, 6 and 7. Seacoal probably evolves gas at a slightly higher temperature than asphaltic materials. Gas from pitch mix evolved somewhat faster initially than seacoal, but the total was less than seacoal and greater than the three asphalts. Gasses from mixes 4, 5 and 7 evolved at a slightly faster rate than from seacoal and pitch but had less total gas. Gilsonite gave off the least amount of smoke during the laboratory testing.Gilsonite and seacoal were compared as additives to system sands. Unpublished data covered recycle sands prepared with the two additives over a period of 20 cycles. Composition of the sand systems used in the tests were as noted in Table VII.

Composition of Sand Mixes

Table VII

Mix	Components	% New Sand	Additions Cycles 1-10	Cycles 11-20
All	System Sand	--	100	100
	New Sand	100	2	2
	Bentonite	8	1.16	0.563
1	(active)	2.2-2.35	2.5	2.8
	Moisture	2.0	0.7	0.338
2	(Approx. %)			
	Seacoal	0.4	0.186	0.078
	(Additive 1%)			
	As No. 1,			
	Except			
	Gilsonite			
	Additive (%)			

Sand physical properties were measured after 20 cycles at two temper water levels and are shown in Table VIII. These data indicate that Gilsonite addition provided improved properties in the system sand. Notable were the higher green tensile and compression strength. Dry compression was not as clearly improved when Gilsonite was compared to seacoal.

Sand Properties After 20 Pours

Table VIII

Mixture	H_2O	Compactability	Permeability	N/cm²	psi	Green Compression N/cm²	Net Tensile psi	N/cm²	Dry Compression psi
1	3.0	32	75	17.4	25.2	0.14	0.20	38.2	55.4
(Seacoal)	3.6	41	80	16.5	23.9	0.14	0.20	58.8	85.3
2	2.5	33	105	22.5	32.7	0.21	0.30	45.1	65.4
Gilsonite	2.9	41	110	18.1	26.2	0.25	0.37	54.9	79.6

More temper water was required in the recycle sand when using seacoal to achieve comparable compactabilities. This result confirms observations regarding moisture level in the laboratory prepared mixes. The higher seacoal level resulted in lower permeability at the same compactability.

Casting finish was evaluated in the recycle sand additive tests. Gilsonite and seacoal were rated as the same in resistance to surface defects. Penetration and sand adherence were somewhat better with the seacoal mixes.

It should be noted that Gilsonite addition level was 0.5% initially as compared to 2% for the seacoal. A higher Gilsonite addition level may have provided improved properties and casting finish due to an increase in volatiles and lustrous carbon. Research by Stanbridge on evaluating casting finish rated Gilsonite and seacoal to be approximately the same. The other materials used in the Stanbridge study were not rated as well.

Previous research work reported that the use of multi-component additives may achieve optimum results, both technically and economically.(8) Petrzela reported that if the carbon film is not renewed on a continuing basis, dissolution and oxidation soon destroys its effectiveness.(9)

In 1973, research showed that seacoal's total volatilization occurred at a somewhat higher temperature than asphaltic material. At 900°F (482.2°C) about 60% of the total volatile (VCM) was evolved from seacoal whereas asphalts evolved about 90% of the total volatiles.(3) It was further stated that the degree of casting peel was generally directly related to the amount of volatiles. The use of a two component carbonaceous additive system (i.e. Sea Coal-Gilsonite) may further improve casting finish due to the extended gassification range.

The type of gasses and the temperature at which they evolve is a major factor in evaluating the various carbons. During the casting process numerous gasses are present in the interface area. These include H_2O, CO, CO_2, N_2, and CH_4. All of these are in a constant state of change during the pouring and solidification. At the interface, the greater the ratio of CO to CO_2 gas, the greater the reducing atmosphere.(10)

Carbonaceous materials, when heated, produce volatile hydrocarbon gasses which subsequently pyrolyze, depositing a layer of pyrolytic carbon on the sand grains and on the surface of the molten metal. Hespers and Wamich(11) and Stanbridge(4) reported lustrous carbon on several additives as follows:

% Lustrous Carbon
Seacoal 8-12
Synthetic Coaldust 11-19
Gilsonite 22-33
Oil Emulsions 26-58
Pitch and Bitumen 34-42
Polystyrene 84-92

Research by Stanbridge evaluating casting finish rated Gilsonite and seacoal approximately the same. The other carbonaceous additives used in this study did not rate as well.(4)

CONCLUSIONS

1. In laboratory new sand mixes with similar 900°F (482.2°C) volatiles, non-seacoal carbonaceous additives provided higher green, dry, baked, and hot strengths at lower additive levels than seacoal.

2. The hot strengths with seacoal and pitch peaked at 1500°F (815.5°C), whereas Gilsonite peaked at 1650°F (899°C). This data indicates some asphaltic materials can be used to produce large castings and in practice Gilsonite is being used to produce ingot molds and large machine tool casings.

3. Improved sand physical properties are achieved using finely pulverized Gilsonite of 274 AFS fineness as compared to the same material at 174 AFS. This data indicates the need for consideration of additive sizing when using different carbonaceous materials in production mixes.

4. Gilsonite and asphalts at approximately one third the level of seacoal and pitch had the same 900°F (482.2°C) volatiles. At this level, loss on ignition with asphalt, and Gilsonite was less than 50% of that obtained with seacoal and pitch while the Gilsonite and asphalts evolved less total gas when compared to seacoal and pitch Gilsonite had the least visible smoke generated in the laboratory tests. The lower gas evolution should reduce ventilation load on the pouring floor.

5. The physical property relationships developed in new sand mixes were confirmed on system sand using Gilsonite as an additive. Casting finish of a Gilsonite mix was equal to seacoal.

6. Based on physical properties developed by the additives used in the study, the additive level must be carefully considered in developing the most cost effective sand system.

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