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Appendices

Appendix 1

The method for the treatment of rice husk to produce silica powder

SiO₂-N

1. Wash rice husk with water 3 times to get rid of impurities such as sand and plant leaves.
2. Wash and soak rice husk in the tank for 2-3 night and after that drain the water out.
3. Put washed rice husk into a beaker; 50 g rice husk : 1000 cc water, and stir at a speed of 300-350 rpm for 3h and then wash with water again and drain water out
4. Dry rice husk at 110 °C for 5h or until it becomes completely dry.
5. Put in the sagger and calcine at 650 °C for 1 h

SiO₂-H

1. Wash rice husk with water 3 times to get rid of impurities
2. Dry in the oven at 110 °C for 3h or until completely dry.
3. Prepare acid solution by using HCl (concentration):
Distilled water in the ratio 1: 10 by volume.
4. Put 50 g of dry rice husk in a beaker with 1000 cc acid solution, stir the solution with a magnetic stirrer while being on a hot plate. The temperature of the hot plate is around 90-100 °C. The treatment goes on for 3 h.

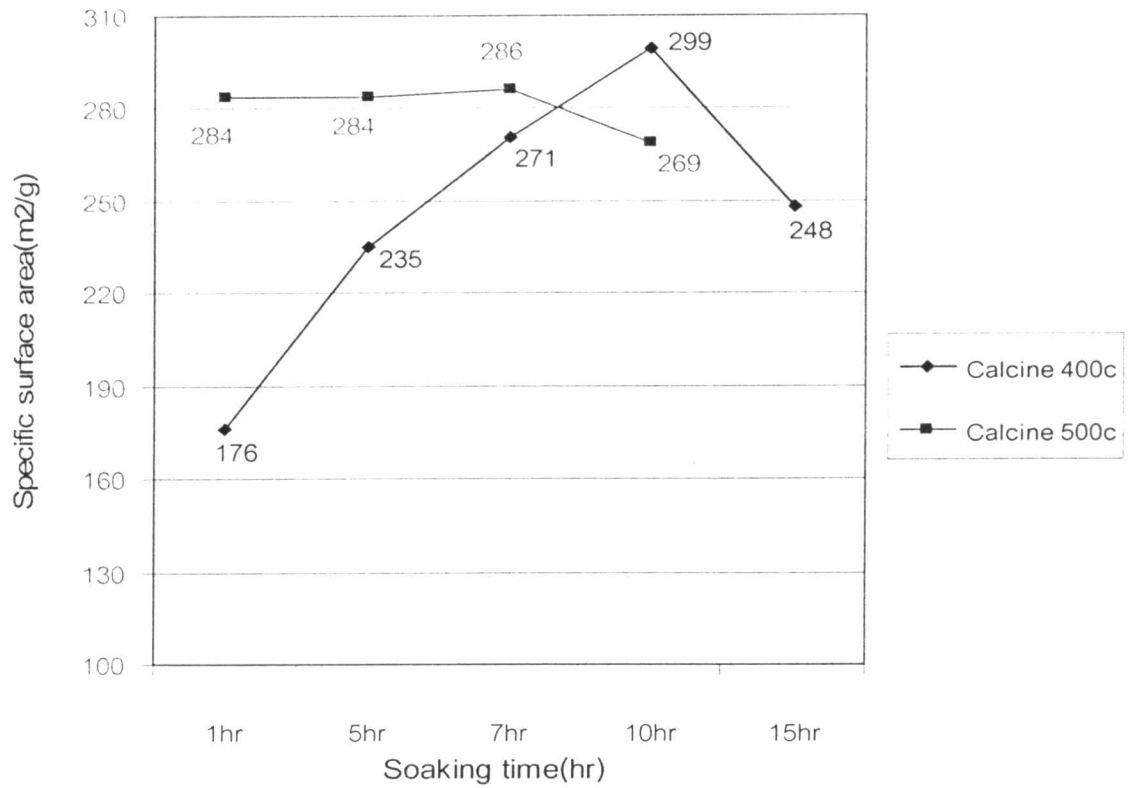
5. Wash treated rice husk by water to get rid of HCl and some alkali on the surface of rice husk.
6. Dry in the oven at 110 °C for 3 h.
7. Calcine in the electric furnace at 650 °C for 1 h.

SiO₂-U

1. Wash rice husk by water 3 times to get rid of impurities
2. Dry in the oven at 110 °C for 3 h.
3. Calcine in the electric furnace at 650 °C for 1 h.

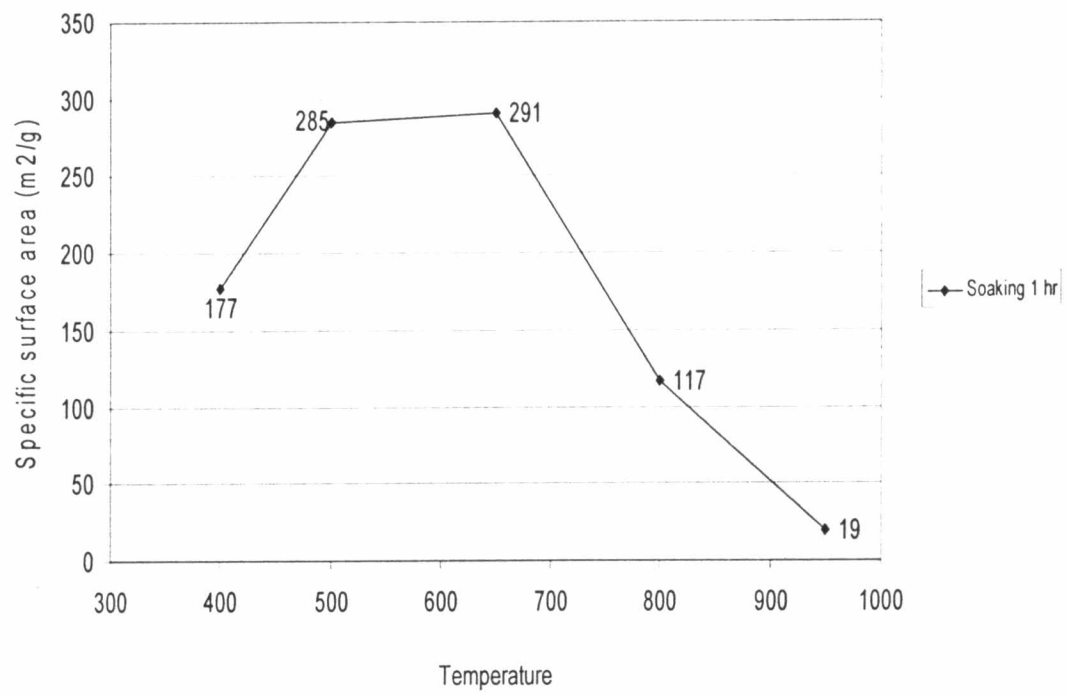
Appendix 2.

Specific surface area of silica obtained from the treatment of rice husk by proprietary method



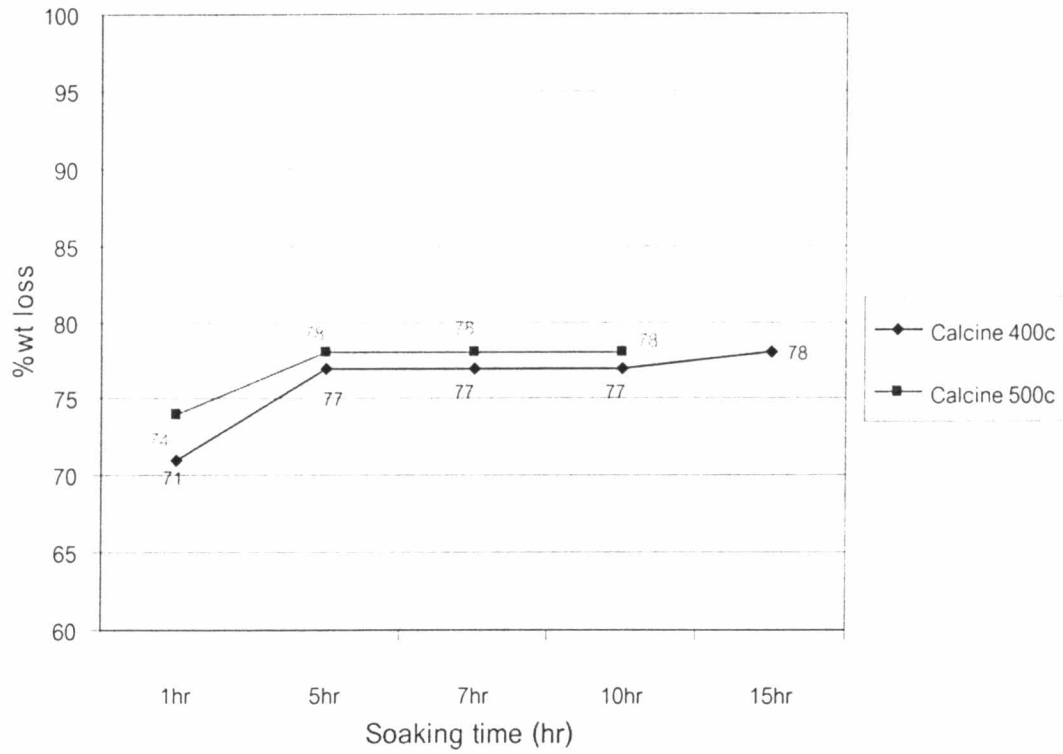
Relationship between soaking time and surface area at various calcining temperatures.

Appendix3



Relationship between surface area of silica powder and calcining temperature for the proprietary method.

Appendix4



Relationship between %weight loss of calcined rice husk and soaking time at various calcining temperatures.

Appendix 5

Compositions of silica powders obtained from different treatments of rice husk

%Oxide	SiO ₂ -H	SiO ₂ -N	SiO ₂ -U	SiO ₂ -Bp1	SiO ₂ -Bp4	SiO ₂ -60°C1	SiO ₂ -NB
SiO ₂	99.06	98.10	97.36	97.57	98.58	97.11	97.66
Al ₂ O ₃	0.8	0.91	1.12	1.1	1.1	1.63	1.71
Fe ₂ O ₃	0.01	0	0.55	0.35	0.01	0	0
Na ₂ O	0	0.04	0.01	0.04	0.03	0	0
CaO	0.06	0.83	1.01	0.19	0.19	0.55	0.56
K ₂ O	0.03	0.07	0.33	0.36	0.05	0.05	0.02
MgO	0	0.03	0.05	0.11	0	0.04	0.03
TiO ₂	0	0	0	0.04	0.02	0	0
MnO ₂	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Sp.Gr(m ² /g)	182	291	9	85	108	240	255

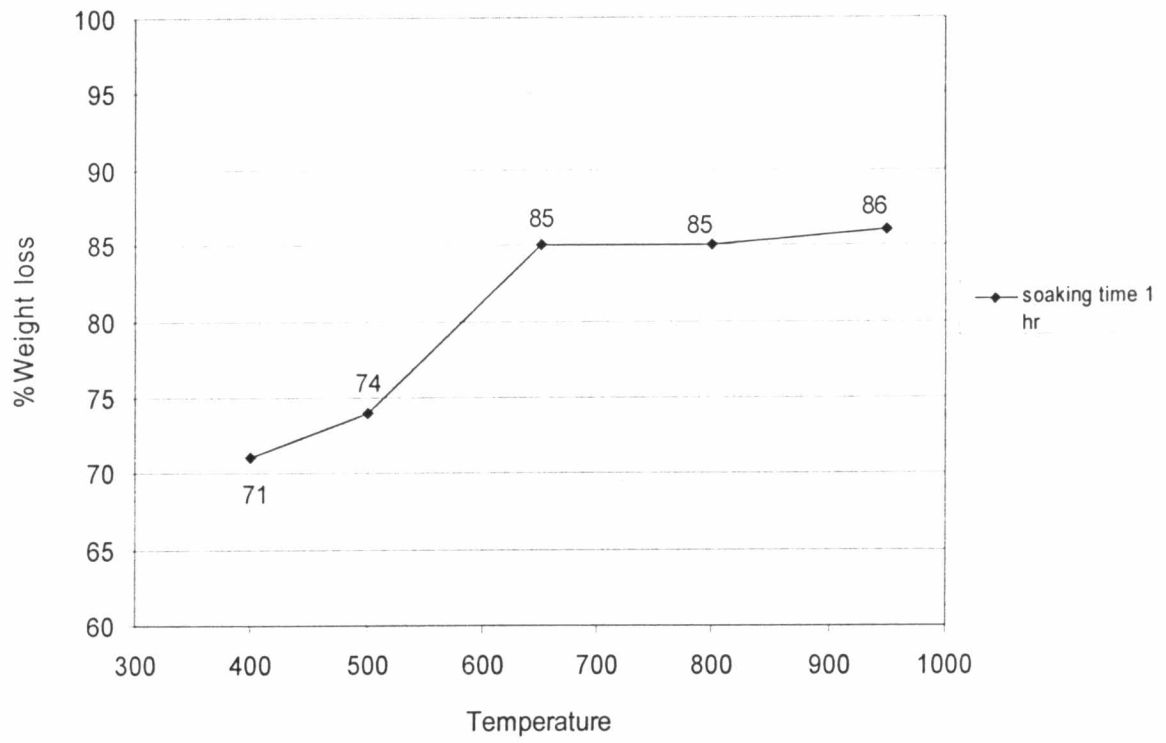
Remark SiO₂-Bp1= Silica powder from rice husk treated by boiling water 1 time

SiO₂-Bp4= Silica powder from rice husk treated by boiling water 4 times

SiO₂-60°C1= Silica powder from rice husk treated by 60°C water 1 time

SiO₂-NB= Silica powder from barley rice husk treated by proprietary method

Appendix6



Relationship between %weight loss of rice husk treated by proprietary method and calcining temperature, soaking time 1 h.

Appendix7

Densities and %water absorption of specimens Formula 1

Formula 1 Temperature 1400 °C

Specimen No	w2	w3	w1	w3-w2	Bulk density	%Water absorption	%of theoretical density
1/1/1	1.0190	1.7621	1.4746	0.7431	1.98	19.5	63.3
1/1/2	1.0211	1.7632	1.4755	0.7421	1.98	19.5	63.3
1/1/3	0.9997	1.7484	1.4668	0.7487	1.95	19.2	62.3
1/2/1	1.0139	1.7332	1.4656	0.7193	2.03	18.3	64.9
1/2/2	0.9998	1.7255	1.4544	0.7257	2.00	18.6	63.9
1/2/3	1.0166	1.7365	1.4687	0.7199	2.03	18.2	64.9
1/3/1	1.0074	1.7085	1.4544	0.7011	2.07	17.5	66.1
1/3/2	1.0099	1.7103	1.4560	0.7004	2.07	17.5	66.1
1/3/3	1.0022	1.7011	1.4486	0.6989	2.07	17.4	66.1

Formula 1 Temperature 1500 °C

Specimen No	w2	w3	w1	w3-w2	Bulk density	%Water absorption	%of theoretical density
1/1/1	1.0296	1.7623	1.4950	0.7327	2.03	17.9	64.9
1/1/2	1.0288	1.762	1.4945	0.7332	2.03	17.9	64.9
1/1/3	0.9998	1.7321	1.4732	0.7323	2.01	17.6	64.2
1/2/1	1.0133	1.7373	1.4831	0.7240	2.04	17.1	65.2
1/2/2	1.0155	1.7401	1.4844	0.7246	2.04	17.2	65.2
1/2/3	1.0128	1.7356	1.4822	0.7228	2.04	17.1	65.2
1/3/1	0.9988	1.7111	1.4822	0.7123	2.07	15.4	66.1
1/3/2	1.0002	1.7123	1.4833	0.7121	2.08	15.4	66.5
1/3/3	0.9981	1.7102	1.4812	0.7121	2.07	15.5	66.1

Formula 1 Temperature 1600 °C

Specimen No.	w2	w3	w1	w3-w2	Bulk density	%water absorption	%of theoretical density
1/1/1	0.9838	1.6654	1.4392	0.6816	2.11	15.7	67.4
1/1/2	0.9811	1.6646	1.4385	0.6835	2.10	15.7	67.1
1/1/3	0.9766	1.6632	1.4371	0.6866	2.09	15.7	66.8
1/2/1	0.9968	1.6579	1.4580	0.6611	2.20	13.7	70.3
1/2/2	0.9971	1.6584	1.4585	0.6613	2.20	13.7	70.3
1/2/3	0.9965	1.6574	1.4566	0.6609	2.20	13.8	70.3
1/3/1	0.9837	1.6242	1.4376	0.6405	2.24	13.0	71.6
1/3/2	0.9856	1.6251	1.4379	0.6395	2.24	13.0	71.6
1/3/3	0.9901	1.6266	1.4388	0.6365	2.25	13.1	71.9

Formula 1 Temperature 1650 °C

Specimen No	w2	w3	w1	w3-w2	Bulk density	%Water absorption	%of theoretical density
1/1/1	1.0417	1.641	1.5218	0.5993	2.53	7.8	80.8
1/1/2	1.0501	1.6501	1.5312	0.6000	2.54	7.8	81.2
1/1/3	1.0454	1.6452	1.5255	0.5998	2.54	7.8	81.2
1/2/1	0.9763	1.5189	1.4280	0.5426	2.62	6.4	83.7
1/2/2	1.0203	1.6101	1.5368	0.5898	2.60	4.8	83.1
1/2/3	0.9801	1.5213	1.4291	0.5412	2.63	6.5	84.0
1/3/1	0.9890	1.5270	1.4392	0.5380	2.67	6.1	85.3
1/3/2	1.0021	1.5301	1.4429	0.5280	2.72	6.0	87.0
1/3/3	0.9855	1.5251	1.4433	0.5396	2.67	5.7	85.2

Formula 1 Temperature 1700 °C

Specimen No.	w2	w3	w1	w3-w2	Bulk density	%Water absorption	%of theoretical density
1/1/1	0.9927	1.4858	1.4836	0.4931	3.00	0.1	95.8
1/1/2	0.9941	1.4851	1.4811	0.4910	3.01	0.3	96.2
1/1/3	0.9877	1.4766	1.4744	0.4889	3.01	0.1	96.2
1/2/1	0.9580	1.4252	1.4241	0.4672	3.04	0.1	97.1
1/2/2	0.9622	1.4301	1.4285	0.4679	3.04	0.1	97.1
1/2/3	0.9665	1.4357	1.4339	0.4692	3.05	0.1	97.3
1/3/1	1.0012	1.4846	1.4845	0.4834	3.06	0.0	97.8
1/3/2	1.0015	1.4855	1.4853	0.484	3.06	0.0	97.8
1/3/3	0.9998	1.4791	1.4784	0.4793	3.08	0.0	98.4

Densities and %water absorption of specimens Formula 2

Formula 2 Temperature 1400 °C

Specimen No	w2	w3	w1	w3-w2	Bulk density	%water absorption	%of theoretical density
2/1/1	0.9980	1.7398	1.4496	0.7418	1.95	20.0	63.7
2/1/2	1.0003	1.7405	1.4501	0.7402	1.95	20.0	63.7
2/1/3	0.9875	1.7288	1.4384	0.7413	1.93	20.2	63.1
2/2/1	0.9776	1.6839	1.4213	0.7063	2.01	18.5	65.7
2/2/2	1.0021	1.7088	1.4471	0.7067	2.04	18.1	66.7
2/2/3	0.9845	1.6912	1.4323	0.7067	2.02	18.1	66.0
2/3/1	0.9562	1.6308	1.3901	0.6746	2.05	17.3	67.0
2/3/2	0.9555	1.6309	1.3922	0.6754	2.06	17.1	67.3
2/3/3	0.9954	1.6911	1.4387	0.6957	2.06	17.5	67.3

Formula 2 Temperature 1500 °C

Specimen No	w2	w3	w1	w3-w2	Bulk density	%water absorption	%of theoretical density
2/1/1	0.9841	1.691	1.4321	0.7069	2.02	18.1	66.0
2/1/2	1.0003	1.7405	1.4671	0.7402	1.98	18.6	64.7
2/1/3	1.0032	1.7288	1.4455	0.7256	1.99	19.6	65.0
2/2/1	0.9566	1.6311	1.3905	0.6745	2.06	17.3	67.3
2/2/2	0.9555	1.6351	1.3887	0.6796	2.04	17.7	66.7
2/2/3	0.9602	1.6415	1.3941	0.6813	2.04	17.7	66.7
2/3/1	0.9611	1.6215	1.3841	0.6604	2.09	17.2	68.3
2/3/2	0.9555	1.6309	1.4022	0.6754	2.07	16.3	67.7
2/3/3	0.9954	1.6911	1.4451	0.6957	2.07	17.0	67.7

Formula 2 Temperature 1600 °C

Specimen No	w2	w3	w1	w3-w2	Bulk density	%water absorption	%of theoretical density
2/1/1	0.9839	1.6899	1.4325	0.706	2.02	18.0	66.0
2/1/2	1.0002	1.7222	1.4755	0.722	2.04	16.7	66.7
2/1/3	1.0032	1.7122	1.4541	0.709	2.04	17.7	66.7
2/2/1	0.9566	1.6211	1.3945	0.6645	2.09	16.2	68.3
2/2/2	0.9555	1.6351	1.3987	0.6796	2.05	16.9	67.0
2/2/3	0.9741	1.6415	1.3989	0.6674	2.09	17.3	68.3
2/3/1	0.9721	1.6215	1.3841	0.6494	2.12	17.2	69.3
2/3/2	0.9585	1.6309	1.4064	0.6724	2.09	16.0	68.3
2/3/3	0.9611	1.6323	1.4074	0.6712	2.09	16.0	68.3

Formula 2 Temperature 1650 °C

Specimen No	w2	w3	w1	w3-w2	Bulk density	%water absorption	%of theoretical density
2/1/1	1.0101	1.5999	1.4826	0.5898	2.51	7.9	82.0
2/1/2	1.0066	1.6101	1.4999	0.6035	2.48	7.3	81.1
2/1/3	1.0032	1.6085	1.4925	0.6053	2.46	7.8	80.4
2/2/1	0.9729	1.5275	1.4294	0.5546	2.57	6.9	84.0
2/2/2	0.9555	1.5033	1.4095	0.5478	2.57	6.7	84.0
2/2/3	1.0025	1.5566	1.4588	0.5541	2.62	6.7	85.6
2/3/1	0.9734	1.5153	1.431	0.5419	2.63	5.9	86.0
2/3/2	0.9557	1.4997	1.4299	0.544	2.62	4.9	85.6
2/3/3	0.9988	1.5333	1.441	0.5345	2.69	6.4	87.9

Formula 2 Temperature 1700 °C

Specimen No	w2	w3	w1	w3-w2	Bulk density	%water absorption	%of theoretical density
2/1/1	0.9799	1.469	1.4662	0.4891	2.99	0.2	97.7
2/1/2	1.0301	1.5533	1.5499	0.5232	2.95	0.2	96.4
2/1/3	1.0288	1.5521	1.5474	0.5233	2.95	0.3	96.4
2/2/1	0.9672	1.4481	1.4428	0.4809	2.99	0.4	97.7
2/2/2	1.0023	1.5033	1.4997	0.501	2.98	0.2	97.4
2/2/3	1.0024	1.5021	1.5003	0.4997	2.99	0.1	97.7
2/3/1	0.9551	1.4262	1.4238	0.4711	3.01	0.2	98.4
2/3/2	0.9557	1.4274	1.4241	0.4717	3.01	0.2	98.4
2/3/3	0.9631	1.4375	1.4332	0.4744	3.01	0.3	98.4

Densities and %water absorption of specimens Formula 3

Formula 3 Temperature 1400 °C

Specimen No.	w2	w3	w1	w3-w2	Bulk density	%Water absorption	%of theoretical density
3/1/1	1.0070	1.7191	1.4452	0.7121	2.02	19.0	63.9
3/1/2	0.9997	1.7177	1.4446	0.7180	2.01	18.9	63.6
3/1/3	0.9966	1.7166	1.4421	0.7200	2.00	19.0	63.3
3/2/1	0.9884	1.6795	1.4201	0.6911	2.05	18.3	64.9
3/2/2	0.9851	1.6751	1.4166	0.6900	2.05	18.2	64.9
3/2/3	0.9923	1.6803	1.4223	0.6880	2.06	18.1	65.2
3/3/1	1.0269	1.7254	1.4710	0.6985	2.10	17.3	66.5
3/3/2	1.0287	1.7263	1.4788	0.6976	2.11	16.7	66.8
3/3/3	1.0188	1.7185	1.4652	0.6997	2.09	17.3	66.1

Formula 3 Temperature 1500 °C

Specimen No.	w2	w3	w1	w3-w2	Bulk density	%Water absorption	%of theoretical density
3/1/1	1.0051	1.7023	1.4498	0.6972	2.07	17.4	65.5
3/1/2	0.9988	1.7145	1.4432	0.7157	2.06	18.8	65.2
3/1/3	0.9988	1.7113	1.4488	0.7125	2.03	18.1	64.2
3/2/1	1.0057	1.7078	1.4584	0.7021	2.07	17.1	65.5
3/2/2	0.9849	1.6747	1.4202	0.6898	2.05	17.9	64.9
3/2/3	1.0033	1.7052	1.4566	0.7019	2.07	17.1	65.5
3/3/1	1.0148	1.7077	1.4712	0.6929	2.12	16.1	67.1
3/3/2	1.0122	1.7052	1.4678	0.693	2.11	16.2	66.8
3/3/3	1.018	1.7185	1.4689	0.7005	2.09	17.0	66.1

Formula 3 Temperature 1600 °C

Specimen No.	w2	w3	w1	w3-w2	Bulk density	%Water absorption	%of theoretical density
3/1/1	1.0104	1.6769	1.466	0.6665	2.19	14.4	69.3
3/1/2	1.0203	1.6871	1.4788	0.6668	2.21	14.1	69.9
3/1/3	0.9988	1.6555	1.4485	0.6567	2.20	14.3	69.6
3/2/1	0.9811	1.6072	1.4211	0.6261	2.26	13.1	71.5
3/2/2	1.0211	1.6747	1.4599	0.6536	2.23	14.7	70.6
3/2/3	0.9833	1.6085	1.4012	0.6252	2.23	14.8	70.6
3/3/1	1.0233	1.6328	1.5441	0.6929	2.22	5.7	70.3
3/3/2	1.0122	1.6254	1.4712	0.6132	2.39	10.5	75.6
3/3/3	1.0174	1.6321	1.4689	0.6147	2.38	11.1	75.3

Formula 3 Temperature 1650 °C

Specimen No.	w2	w3	w1	w3-w2	Bulk density	%Water absorption	%of theoretical density
3/1/1	0.9890	1.5424	1.443	0.5534	2.60	6.9	82.3
3/1/2	1.0111	1.5632	1.4631	0.5521	2.64	6.8	83.5
3/1/3	0.9987	1.5524	1.4525	0.5537	2.62	6.9	82.9
3/2/1	0.985	1.5244	1.4323	0.5394	2.65	6.4	83.9
3/2/2	0.9855	1.5242	1.4321	0.5387	2.65	6.4	83.9
3/2/3	0.9833	1.5225	1.4388	0.5392	2.66	5.8	84.2
3/3/1	0.9848	1.523	1.4389	0.5382	2.67	5.8	84.5
3/3/2	1.0154	1.563	1.4687	0.5476	2.67	6.4	84.5
3/3/3	0.9855	1.5236	1.4398	0.5381	2.67	5.8	84.5

Formula 3 Temperature 1700 °C

Specimen No.	w2	w3	w1	w3-w2	Bulk density	%Water absorption	%of theoretical density
3/1/1	0.9477	1.4359	1.4312	0.4882	2.92	0.3	92.5
3/1/2	0.9546	1.4435	1.4323	0.4889	2.92	0.8	92.4
3/1/3	0.9712	1.4587	1.4356	0.4875	2.94	1.6	92.9
3/2/1	0.9642	1.4613	1.4545	0.4971	2.92	0.5	92.4
3/2/2	0.9741	1.4701	1.4623	0.496	2.94	0.5	93.0
3/2/3	0.9651	1.4611	1.4547	0.496	2.92	0.4	92.4
3/3/1	0.9788	1.4599	1.4523	0.4811	3.01	0.5	95.3
3/3/2	1.0111	1.4998	1.4923	0.4887	3.04	0.5	96.2
3/3/3	0.9812	1.4603	1.4551	0.4791	3.03	0.4	95.9

Density and %water absorption of specimens Formula 1-S

Formula 1-S Temperature 1400 °C

Specimen No.	w2	w3	w1	w3-w2	Bulk density	%Water absorption	%of theoretical density
1/S/1	0.9789	1.6825	1.4207	0.7036	2.01	18.4	64.3
1/S/2	0.9997	1.7177	1.4446	0.718	2.01	18.9	64.1
1/S/3	0.9966	1.7166	1.4421	0.72	2.00	19.0	63.8

Formula 1-S Temperature 1500 °C

Specimen No.	w2	w3	w1	w3-w2	Bulk density	%Water absorption	%of theoretical density
1/S/1	0.9838	1.6674	1.4282	0.6836	2.08	16.7	66.5
1/S/2	0.9997	1.6987	1.4445	0.699	2.06	17.6	65.8
1/S/3	0.9821	1.6655	1.428	0.6834	2.08	16.6	66.5

Formula 1-S Temperature 1600 °C

Specimen No.	w2	w3	w1	w3-w2	Bulk density	%Water absorption	%of theoretical density
1/S/1	0.9722	1.5434	1.4201	0.5712	2.48	8.7	79.2
1/S/2	0.9755	1.5456	1.4233	0.5701	2.49	8.6	79.6
1/S/3	0.9811	1.5511	1.4280	0.5700	2.50	8.6	79.9

Formula 1-S Temperature 1650 °C

Specimen No.	w2	w3	w1	w3-w2	Bulk density	%Water absorption	%of theoretical density
1/S/1	0.9635	1.4609	1.4593	0.4974	2.93	0.1	93.6
1/S/2	0.9655	1.4611	1.4598	0.4956	2.94	0.1	93.9
1/S/3	0.9701	1.4681	1.4663	0.4980	2.94	0.1	93.9

Formula 1-S Temperature 1700 °C

Specimen No.	w2	w3	w1	w3-w2	Bulk density	%Water absorption	%of theoretical density
1/S/1	0.9778	1.4495	1.4487	0.4717	3.06	0.1	97.8
1/S/2	0.9723	1.4436	1.4435	0.4713	3.05	0.0	97.4
1/S/3	0.9701	1.4423	1.4411	0.4722	3.04	0.1	97.1

Density and %water absorption of specimens Formula 1-S-A

Formula 1-S-A Temperature 1400 °C

Specimen No.	w2	w3	w1	w3-w2	Bulk density	%Water absorption	%of theoretical density
1/S/A/1	0.7641	1.4213	1.1349	0.6572	1.72	25.24	55.01
1/S/A/2	0.7741	1.4306	1.1432	0.6565	1.74	25.14	55.47
1/S/A/3	0.7688	1.4226	1.1388	0.6538	1.74	24.92	55.48

Formula 1-S-A Temperature 1500 °C

Specimen No.	w2	w3	w1	w3-w2	Bulk density	%Water absorption	%of theoretical density
1/S/A/1	0.7501	1.2484	1.1381	0.4983	2.28	9.7	72.8
1/S/A/2	0.7512	1.2464	1.1361	0.4952	2.29	9.7	73.2
1/S/A/3	0.7588	1.2499	1.1397	0.4911	2.31	9.7	73.8

Formula 1-S-A Temperature 1600 °C

Specimen No.	w2	w3	w1	w3-w2	Bulk density	%Water absorption	%of theoretical density
1/S/A/1	0.7638	1.1721	1.1689	0.4083	2.85	0.3	91.1
1/S/A/2	0.7788	1.1887	1.1723	0.4099	2.85	1.4	91.1
1/S/A/3	0.7711	1.1733	1.1578	0.4022	2.87	1.3	91.7

Formula 1-S-A Temperature 1650 °C

Specimen No.	w2	w3	w1	w3-w2	Bulk density	%Water absorption	%of theoretical density
1/S/A/1	0.7660	1.1627	1.1577	0.3967	2.91	0.4	93.0
1/S/A/2	0.7692	1.1656	1.1599	0.3964	2.92	0.5	93.3
1/S/A/3	0.7651	1.1621	1.1569	0.3970	2.91	0.4	93.0

Formula 1-S-A Temperature 1700 °C

Specimen No.	w2	w3	w1	w3-w2	Bulk density	%Water absorption	%of theoretical density
1/S/A/1	0.7381	1.1183	1.1166	0.3802	2.93	0.2	93.6
1/S/A/2	0.7455	1.1253	1.1234	0.3798	2.95	0.2	94.3
1/S/A/3	0.7671	1.1621	1.1611	0.3950	2.93	0.1	93.6

Density and %water absorption of specimens Formula 1-A

Formula 1-A Temperature 1400 °C

Specimen No.	w2	w3	w1	w3-w2	Bulk density	%Water absorption	%of theoretical density
1/A/1	0.7421	1.2488	0.8944	0.5067	1.76	39.6	56.2
1/A/2	0.7466	1.2455	0.8932	0.4989	1.78	39.4	57.0
1/A/3	0.7511	1.2522	0.9023	0.5011	1.80	38.8	57.4

Formula 1-A Temperature 1500 °C

Specimen No.	w2	w3	w1	w3-w2	Bulk density	%Water absorption	%of theoretical density
1/A/1	0.7508	1.2487	1.1384	0.4979	2.28	9.7	72.8
1/A/2	0.7502	1.2455	1.1356	0.4953	2.29	9.7	73.2
1/A/3	0.7512	1.2465	1.1397	0.4953	2.29	9.4	73.2

Formula 1-A Temperature 1600 °C

Specimen No.	w2	w3	w1	w3-w2	Bulk density	%Water absorption	%of theoretical density
1/A/1	0.8190	1.2620	1.2537	0.4430	2.82	0.7	90.1
1/A/2	0.8154	1.2573	1.2501	0.4419	2.82	0.6	90.1
1/A/3	0.8233	1.2625	1.2521	0.4392	2.84	0.8	90.7

Formula 1-A Temperature 1650 °C

Specimen No.	w2	w3	w1	w3-w2	Bulk density	%Water absorption	%of theoretical density
1/A/1	0.7292	1.1018	1.0988	0.3726	2.94	0.3	93.9
1/A/2	0.7411	1.1123	1.1023	0.3712	2.96	0.9	94.6
1/A/3	0.7288	1.1003	1.0955	0.3715	2.94	0.4	93.9

Formula 1-A Temperature 1700 °C

Specimen No.	w2	w3	w1	w3-w2	Bulk density	%Water absorption	%of theoretical density
1/A/1	0.7509	1.1310	1.1296	0.3801	2.96	0.1	94.6
1/A/2	0.7364	1.1111	1.1108	0.3747	2.96	0.0	94.6
1/A/3	0.7287	1.1006	1.0957	0.3719	2.94	0.4	93.9

Density and %water absorption of specimens Formula 1-U

Formula 1-U Temperature 1400 °C

Specimen No.	w2	w3	w1	w3-w2	Bulk density	%Water absorption	%of theoretical density
1/U/1	0.9289	1.6331	1.3321	0.7042	1.89	22.6	60.4
1/U/2	0.9433	1.6541	1.3601	0.7108	1.91	21.6	61.0
1/U/3	0.9421	1.6523	1.3587	0.7102	1.91	21.6	61.0

Formula 1-U Temperature 1500 °C

Specimen No.	w2	w3	w1	w3-w2	Bulk density	%Water absorption	%of theoretical density
1/U/1	1.0138	1.8046	1.5121	0.7908	1.91	19.3	61.0
1/U/2	1.0101	1.8023	1.5102	0.7922	1.90	19.3	60.7
1/U/3	1.0203	1.8155	1.5236	0.7952	1.91	19.2	61.0

Formula 1-U Temperature 1600 °C

Specimen No.	w2	w3	w1	w3-w2	Bulk density	%Water absorption	%of theoretical density
1/U/1	1.0155	1.8001	1.5265	0.7846	1.94	17.9	62.0
1/U/2	1.0198	1.8023	1.5323	0.7825	1.95	17.6	62.3
1/U/3	1.0202	1.8155	1.5455	0.7953	1.94	17.5	62.0

Formula 1-U Temperature 1650 °C

Specimen No.	w2	w3	w1	w3-w2	Bulk density	%Water absorption	%of theoretical density
1/U/1	0.9233	1.4496	1.4372	0.5264	2.72	0.9	87.0
1/U/2	0.9310	1.4575	1.4441	0.5265	2.73	0.9	87.4
1/U/3	0.9234	1.4485	1.4366	0.5251	2.73	0.8	87.1

Formula 1-U Temperature 1700 °C

Specimen No.	w2	w3	w1	w3-w2	Bulk density	%Water absorption	%of theoretical density
1/U/1	0.9623	1.5022	1.4988	0.5399	2.77	0.2	88.5
1/U/2	0.9655	1.5032	1.4999	0.5377	2.78	0.2	88.8
1/U/3	0.9721	1.5125	1.5021	0.5404	2.77	0.7	88.5

Density and %water absorption of specimens Formula 1-U-G

Formula 1-U-G Temperature 1400 °C

Specimen No.	w2	w3	w1	w3-w2	Bulk density	%Water absorption	%of theoretical density
1/U/G/1	0.7652	1.3277	1.0945	0.5625	1.94	21.3	62.0
1/U/G/2	0.7711	1.3335	1.1002	0.5624	1.95	21.2	62.3
1/U/G/3	0.7621	1.3242	1.0921	0.5621	1.94	21.3	62.0

Formula 1-U-G Temperature 1500 °C

Specimen No.	w2	w3	w1	w3-w2	Bulk density	%Water absorption	%of theoretical density
1/U/G/1	0.7500	1.2527	1.1771	0.5027	2.33	6.4	74.4
1/U/G/2	0.7523	1.2551	1.1791	0.5028	2.34	6.4	74.8
1/U/G/3	0.7621	1.2662	1.1811	0.5041	2.34	7.2	74.8

Formula 1-U-G Temperature 1600 °C

Specimen No.	w2	w3	w1	w3-w2	Bulk density	%Water absorption	%of theoretical density
1/U/G/1	0.7152	1.1815	1.173	0.4663	2.51	0.7	80.2
1/U/G/2	0.7211	1.1866	1.1791	0.4655	2.53	0.6	80.8
1/U/G/3	0.7235	1.1884	1.1811	0.4649	2.53	0.6	80.8

Formula 1-U-G Temperature 1650 °C

Specimen No.	w2	w3	w1	w3-w2	Bulk density	%Water absorption	%of theoretical density
1/U/G/1	0.7352	1.1876	1.1849	0.4524	2.61	0.2	83.4
1/U/G/2	0.7311	1.1866	1.1851	0.4555	2.59	0.1	82.7
1/U/G/3	0.7299	1.1826	1.1801	0.4527	2.60	0.2	83.1

Formula 1-U-G Temperature 1700 °C

Specimen No.	w2	w3	w1	w3-w2	Bulk density	%Water absorption	%of theoretical density
1/U/G/1	0.7253	1.1670	1.1655	0.4417	2.63	0.1	84.0
1/U/G/2	0.7284	1.1681	1.1658	0.4397	2.64	0.2	84.4
1/U/G/3	0.7298	1.1826	1.1801	0.4528	2.60	0.2	83.1

Density and %water absorption of specimens Formula 1-S-G

Formula 1-S-G Temperature 1400 °C

Specimen No	w2	w3	w1	w3-w2	Bulk density	%water absorption	%of theoretical density
1/S/G/1	0.7543	1.4108	1.1341	0.6565	1.72	24.4	55.0
1/S/G/2	0.7654	1.4221	1.1347	0.6567	1.72	25.3	55.0
1/S/G/3	0.7689	1.4221	1.1366	0.6532	1.73	25.1	55.3

Formula 1-S-G Temperature 1500 °C

Specimen No	w2	w3	w1	w3-w2	Bulk density	%water absorption	%of theoretical density
1/S/G/1	0.7521	1.2484	1.1366	0.4963	2.28	9.8	72.8
1/S/G/2	0.7613	1.2554	1.1345	0.4941	2.29	10.7	72.8
1/S/G/3	0.7598	1.2489	1.1278	0.4891	2.30	10.7	73.5

Formula 1-S-G Temperature 1600 °C

Specimen No	w2	w3	w1	w3-w2	Bulk density	%water absorption	%of theoretical density
1/S/G/1	0.7622	1.1733	1.1711	0.4111	2.84	0.2	90.7
1/S/G/2	0.771	1.1722	1.1545	0.4012	2.87	1.5	91.7
1/S/G/3	0.7722	1.1732	1.1524	0.401	2.87	1.8	91.5

Formula 1-S-G Temperature 1650 °C

Specimen No	w2	w3	w1	w3-w2	Bulk density	%water absorption	%of theoretical density
1/S/G/1	0.7656	1.1632	1.1588	0.3976	2.91	0.4	92.8
1/S/G/2	0.7799	1.1788	1.1721	0.3989	2.93	0.6	93.6
1/S/G/3	0.7661	1.1623	1.1598	0.3962	2.92	0.2	93.2

Formula 1-S-G Temperature 1700 °C

Specimen No	w2	w3	w1	w3-w2	Bulk density	%water absorption	%of theoretical density
1/S/G/1	0.7712	1.1633	1.1612	0.3921	2.95	0.2	94.2
1/S/G/2	0.7802	1.1764	1.1754	0.3962	2.96	0.1	94.6
1/S/G/3	0.7713	1.1643	1.1633	0.393	2.95	0.1	94.2

Density and %water absorption of specimens Formula 2-S-G

Formula 2-S-G Temperature 1400 °C

Specimen No	w2	w3	w1	w3-w2	Bulk density	%water absorption	%of theoretical density
2/S/G/1	1.0231	1.8428	1.5048	0.8197	1.83	22.5	58.5
2/S/G/2	1.0258	1.8425	1.5041	0.8167	1.84	22.5	58.8
2/S/G/3	1.0174	1.8345	1.4967	0.8171	1.83	22.6	58.5

Formula 2-S-G Temperature 1500 °C

Specimen No	w2	w3	w1	w3-w2	Bulk density	%water absorption	%of theoretical density
2/S/G/1	0.9235	1.514	1.3637	0.5905	2.30	11.0	73.5
2/S/G/2	0.9435	1.5351	1.3845	0.5916	2.33	10.9	74.4
2/S/G/3	0.9411	1.5322	1.3755	0.5911	2.32	11.4	74.1

Formula 2-S-G Temperature 1600 °C

Specimen No	w2	w3	w1	w3-w2	Bulk density	%water absorption	%of theoretical density
2/S/G/1	0.8129	1.3148	1.2007	0.5019	2.39	9.5	76.4
2/S/G/2	0.9431	1.5342	1.4056	0.5911	2.37	9.1	75.7
2/S/G/3	0.8325	1.3346	1.2111	0.5021	2.40	10.2	76.7

Formula 2-S-G Temperature 1650 °C

Specimen No	w2	w3	w1	w3-w2	Bulk density	%water absorption	%of theoretical density
2/S/G/1	0.9823	1.5594	1.4517	0.5771	2.51	7.4	80.2
2/S/G/2	0.9745	1.5423	1.4284	0.5678	2.51	8.0	80.2
2/S/G/3	0.9856	1.5612	1.4533	0.5756	2.52	7.4	80.4

Formula 2-S-G Temperature 1700 °C

Specimen No	w2	w3	w1	w3-w2	Bulk density	%water absorption	%of theoretical density
2/S/G/1	0.9954	1.5641	1.4725	0.5687	2.58	6.2	82.4
2/S/G/2	0.9766	1.5466	1.4688	0.5700	2.57	5.3	82.1
2/S/G/3	0.9845	1.5523	1.4678	0.5678	2.58	5.8	82.4

Density and %water absorption of specimens Formula 1-MS

Formula 1-MS is a set of specimens fabricated from mullite powder sintered at 1400 °C for 5 h, crushed in a mortar and then pressed at 40 MPa.

Formula 1-MS Temperature 1400 c

Specimen No.	w2	w3	w1	w3-w2	Bulk density	%Water absorption	%of theoretical density
1/MS	0.9789	1.6829	1.421	0.704	2.01	18.4	64.3

Formula 1-MS Temperature 1500 c

Specimen No.	w2	w3	w1	w3-w2	Bulk density	%Water absorption	%of theoretical density
1/MS	0.9843	1.6665	1.4301	0.6822	2.09	16.5	66.5

Formula 1-MS Temperature 1600 c

Specimen No.	w2	w3	w1	w3-w2	Bulk density	%Water absorption	%of theoretical density
1/MS	0.7185	1.1834	1.1721	0.4649	2.51	1.0	80.2

Formula 1-MS Temperature 1650 c

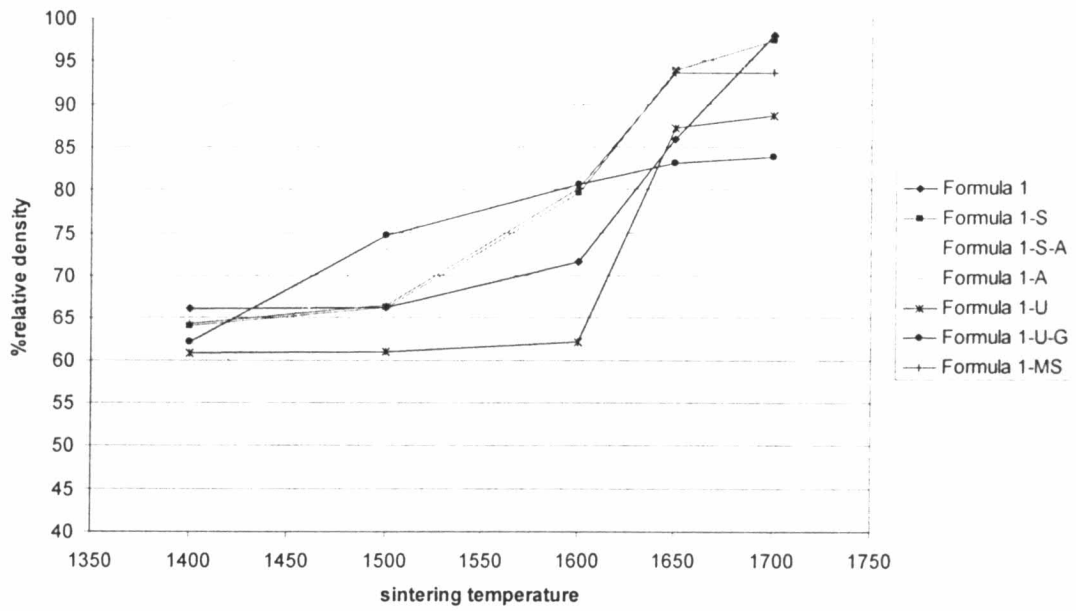
Specimen No.	w2	w3	w1	w3-w2	Bulk density	%Water absorption	%of theoretical density
1/MS	0.7671	1.1621	1.1601	0.395	2.93	0.2	93.6

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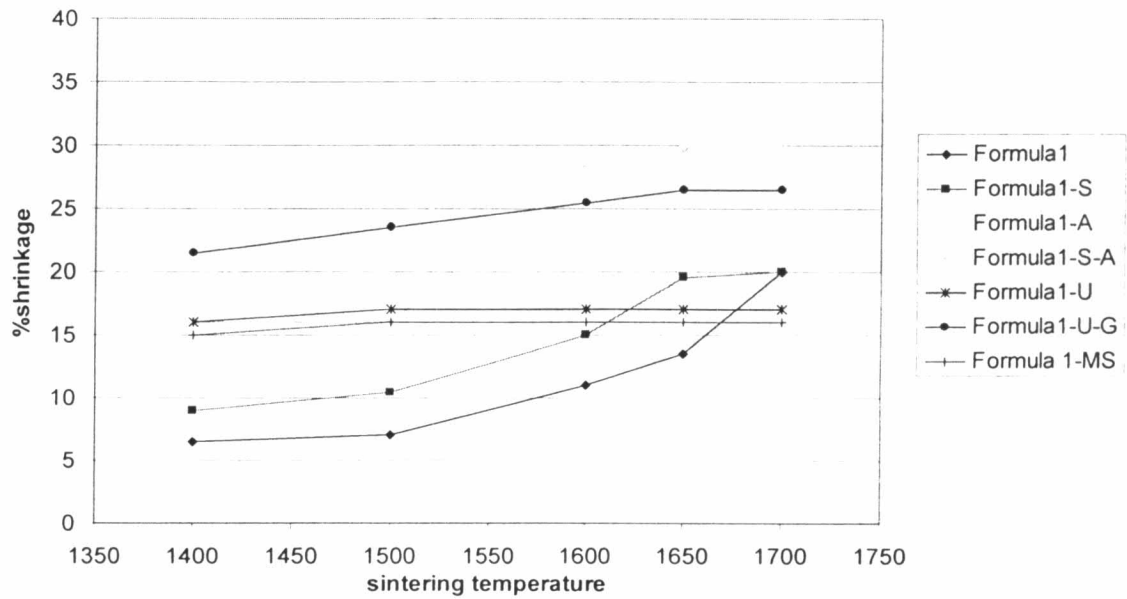
Formula 1-MS Temperature 1700 c

Specimen No.	w2	w3	w1	w3-w2	Bulk density	%Water absorption	%of theoretical density
1/MS	0.7391	1.1185	1.1171	0.3794	2.94	0.1	93.6

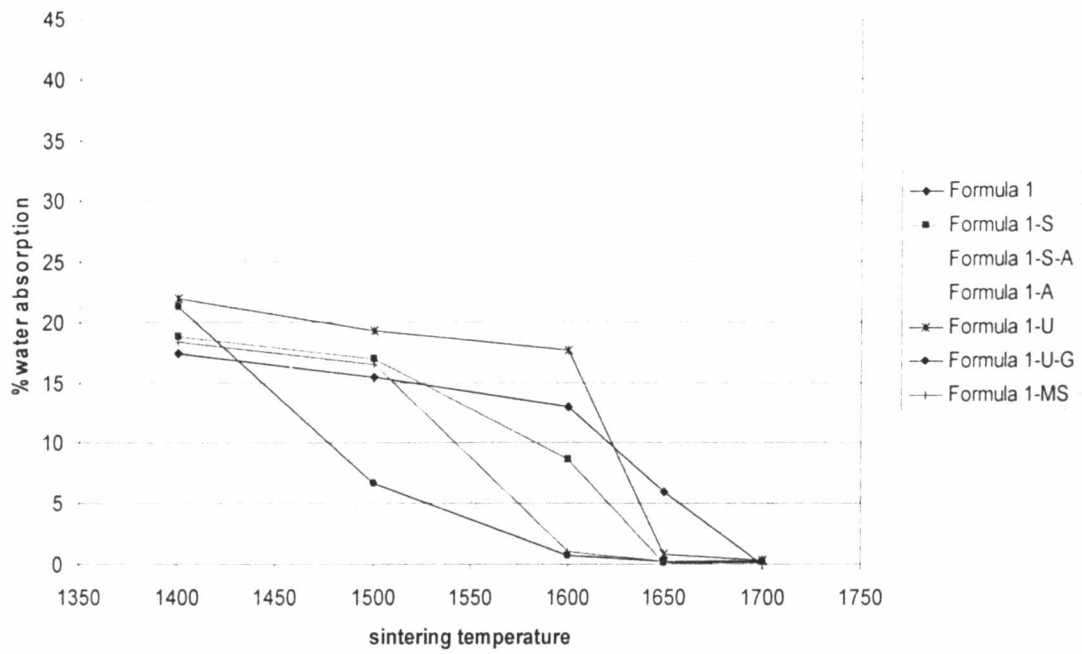
Appendix8



Relationship between relative density and sintering temperature of each formula.



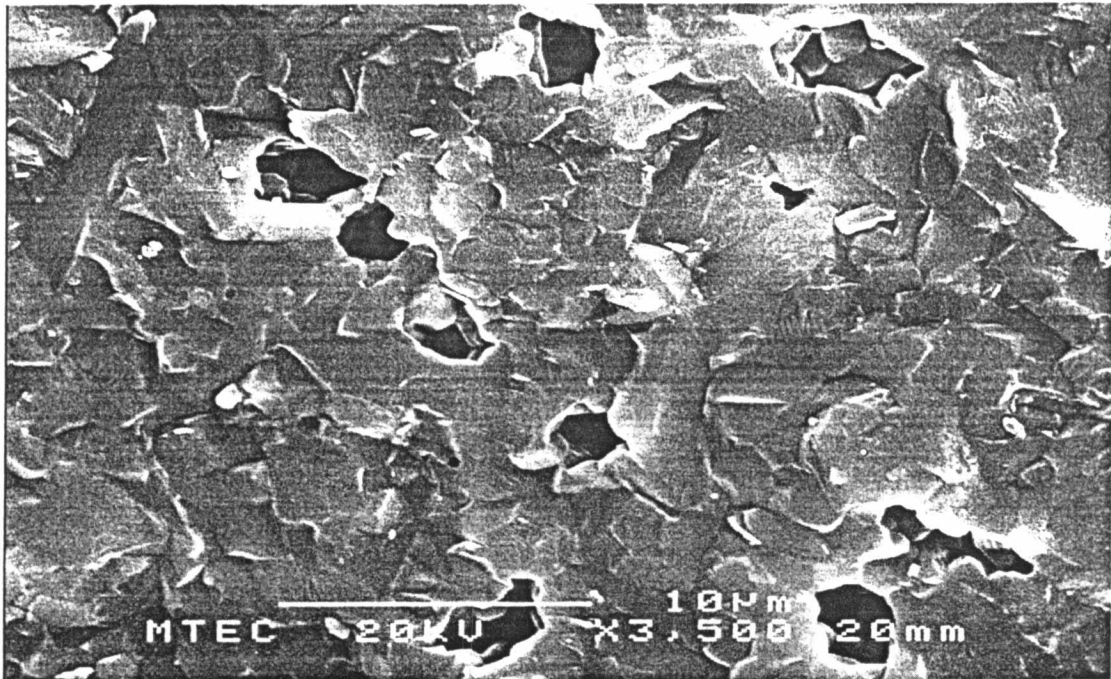
Relationship between shrinkage and sintering temperature of each formula.



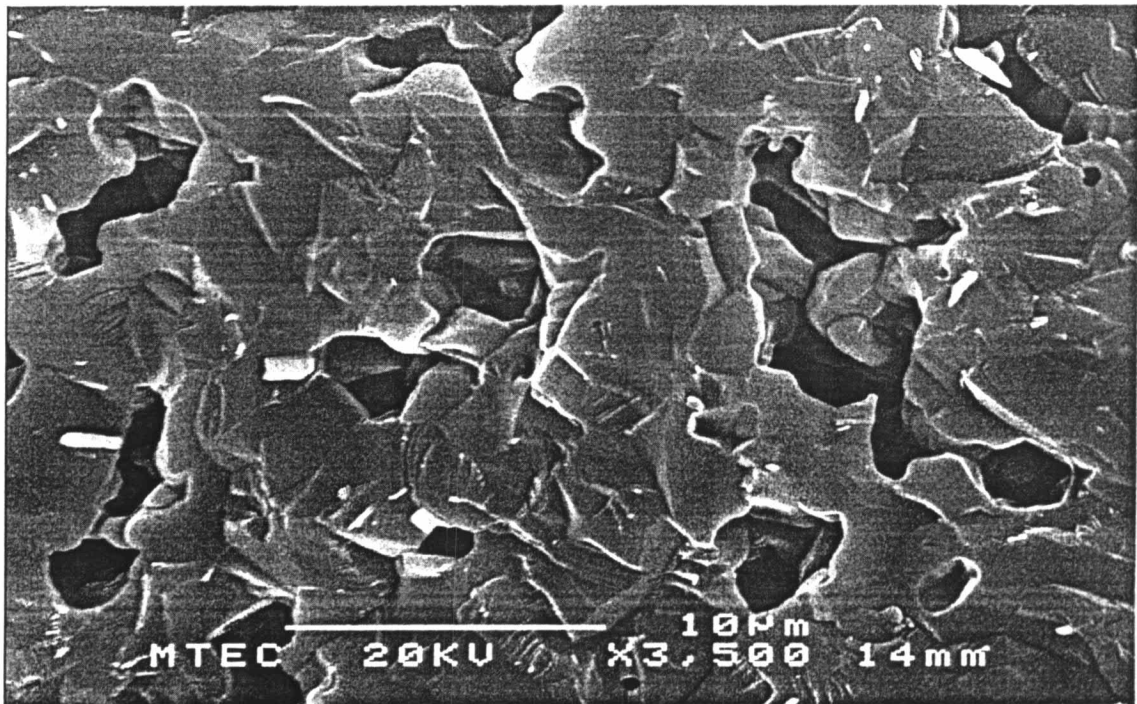
Relationship between water absorption and sintering temperature.

Appendix9

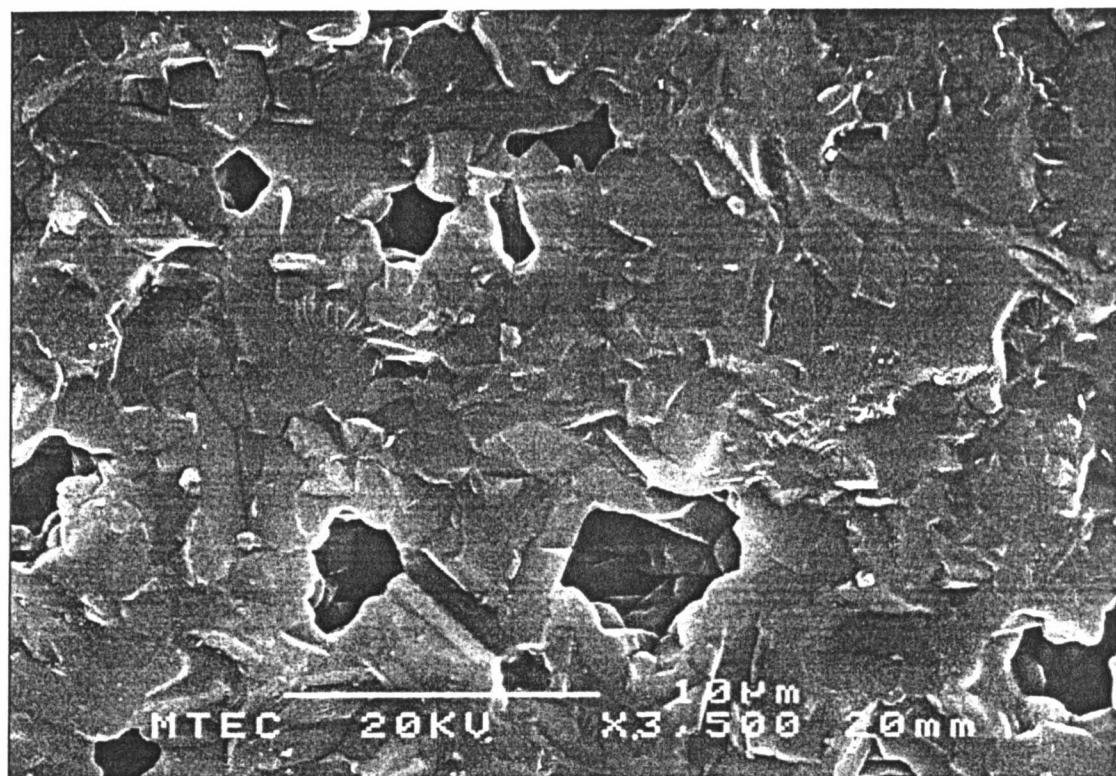
SEM micrographs of fractured specimen after bending strength test(sintered at 1700 °C)



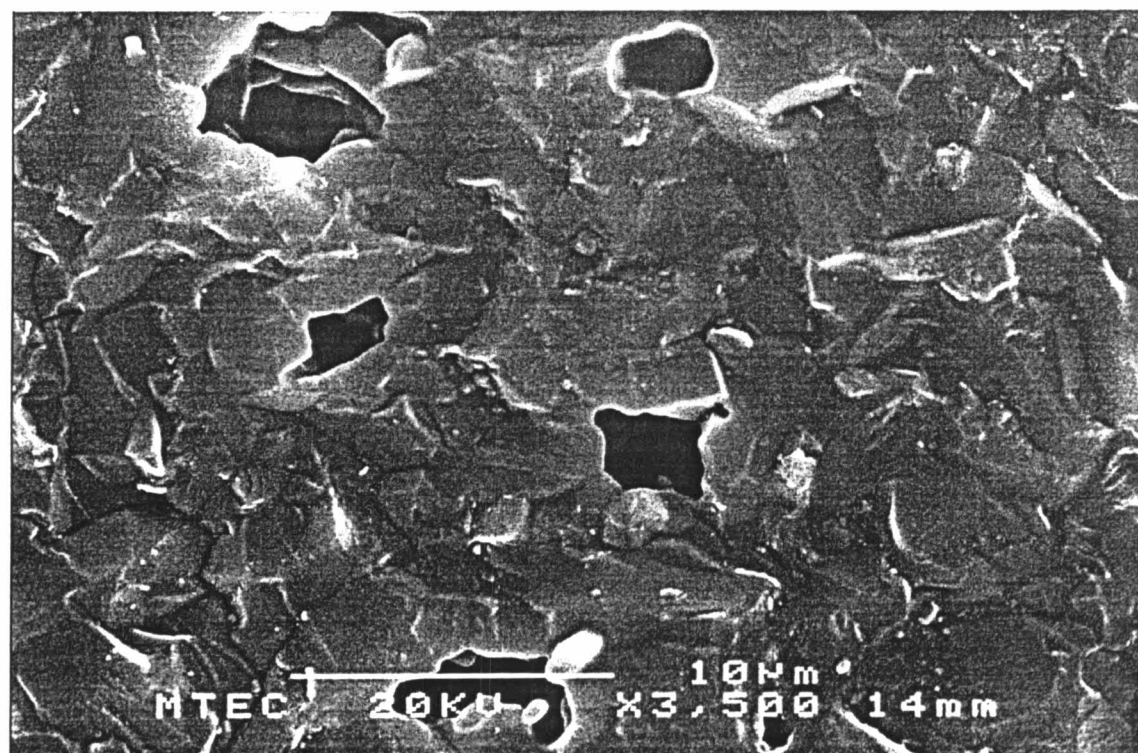
Formula 1



Formula 1-A



Formula 1-S



Formula 1-S-A

Biography

Mr. Kachin Saiintawong was born on the 9th of March 1968, in Bangkok. After graduation with a Bachelor Degree in Ceramic and Materials Science from Faculty of Science, Chulalongkorn University in 1992, he joined Thai Ceramic Company, an incorporated company of Siam Cement Group, until 2001. He enrolled in Master Degree course in Ceramic Technology, Faculty of Science, Chulalongkorn University in 2002 and graduated in June 2004.