A Literature-based Dataset Containing Statistical Compositions and Reactivities of Commercial and Novel Supplementary Cementitious Materials

Dataset Version 1.0

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DATASET SPECIFICATIONS

Title of Dataset	A Literature-based Dataset Containing Statistical Compositions and Reactivities of Commercial and Novel Supplementary Cementitious Materials
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Abstract for the dataset	This dataset contains the chemical composition and reactivities of commercially used SCMs such as silica fume, Class-F and Class-C fly ashes, slags, and calcined clays. The dataset also includes the chemical composition and reactivity (where available) for several SCMs that are currently not specified in standard specifications by ASTM or AASHTO such as fly ashes not conforming to ASTM C618, bottom ashes, and pumices. This dataset can be used (i) for the classification of SCMs based on their statistics (in terms of composition and reactivity), (ii) as an input for predicting the performance of cementitious systems made with SCMs using thermodynamic modeling, (iii) generating realistic compositional and reactivity data for cementitious materials using techniques such as Monte-Carlo method, and (iv) for studying the feasibility of the use of novel SCMs in concrete based on the predicted performance of concrete made with these SCMs.
Licenses/restrictions placed on the data	
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Subject area	Civil Engineering, Infrastructure Materials
Keywords	Portland cement, cement, ordinary Portland cement, OPC, supplementary cementitious materials, SCM, statistics, pozzolanic reactivity, reactivity, silica Fume, fly ash, slag, calcined clay, pumice, off-spec SCM.
Methodological information	Compositional and reactivity information obtained from a comprehensive literature review and testing at Oregon State University. Some of the published data in the literature were received in the electronic format from some sources such as the University of Miami. The testing for chemical composition and reactivity was done through X-Ray Fluorescence (XRF) and the Pozzolanic Reactivity Test (PRT), respectively. Data is provided in raw table format. A summary table of statistical information is also provided. References for all data are cited in the dataset.

Data and file Overview	**<u>File List:</u>** **References.csv:** Includes all references that are cited in the data tables. **SilicaFume.csv:** The data for un-densified and densified silica fume and their references **FlyAsh.csv:** The data for the chemical composition and the DOR* of fly ashes (Class C, F, and off-spec) and their references **BottomAsh.csv:** The data for the chemical composition and the DOR* of bottom ashes and their references **Slag.csv:** The data for the chemical composition and the DOR* of slags and their references **CalcinedClay.csv:** The data for the chemical composition and the DOR* of calcined clays and their references **Pumice.csv:** The data for the chemical composition and the DOR* of pumice and their references **<u>Relationship between files:</u>** The first column in the datafiles are reference numbers that are listed in the references.csv file. **<u>Formats:</u>** The files are in the form of comma separated values (csv).

DISCLAIMER

The dataset is intended solely for academic and educational purposes and not for making engineering or legal decisions. The dataset is presented without any warranties with respect to its accuracy or how it is used. Authors also note that the dataset may not contain all the data available on the subject and might be intentionally (based on scientific reasoning) or unintentionally excluding some data in the literature. Every effort is made not to introduce errors; however, it is acknowledged that the dataset might contain errors originating from the sources in the literature or that are introduced during the data collection process. The dataset contains data from various part of the world and is not specific to a geography. The geographic source of the data should be obtained from the cited papers and reports from which the dataset was collected.

AUTHOR DECLARATION

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

CITATION

When this dataset is used in a publication, this document should be cited as follows:

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RELATED RESEARCH ARTICLES AND REPORTS

Parts of this dataset have been used in the following publications that are cited in this document [1-16]:

[1] V.J. Azad, A.R. Erbektas, C.Y. Qiao, O.B. Isgor, W.J. Weiss, Relating the Formation Factor and Chloride Binding Parameters to the Apparent Chloride Diffusion Coefficient of Concrete, J. Mater. Civ. Eng., 31 (2019).

[2] V.J. Azad, P. Suraneni, O.B. Isgor, W.J. Weiss, Interpreting the Pore Structure of Hydrating Cement Phases Through a Synergistic Use of the Powers-Brownyard Model, Hydration Kinetics, and Thermodynamic Calculations, Advances in Civil Engineering Materials, 6 (2017) 1-16.

[3] K. Bharadwaj, R.M. Ghantous, F. Sahan, O.B. Isgor, W.J. Weiss, Predicting pore volume, compressive strength, pore connectivity, and formation factor in cementitious pastes containing fly ash, Cement Concrete Comp, 122 (2021).

[4] K. Bharadwaj, D. Glosser, M.K. Moradllo, O.B. Isgor, W.J. Weiss, Toward the prediction of pore volumes and freeze-thaw performance of concrete using thermodynamic modelling, Cement and Concrete Research, 124 (2019).

[5] K. Bharadwaj, O.B. Isgor, W.J. Weiss, A Simplified Approach to Determine the Pozzolanic Reactivity of Commercial Supplementary Cementitious Materials, Concr. Int., 44 (2022) 27-32.

[6] K. Bharadwaj, O.B. Isgor, W.J. Weiss, K. Chopperla, C. A., D. Glosser, J. Ideker, D. Trejo, A new mixture proportioning method for performance-based concrete, ACI Mater. J., 119 (2022).

[7] D. Glosser, V.J. Azad, P. Suraneni, O.B. Isgor, W.J. Weiss, Extension of Powers-Brownyard Model to Pastes Containing Supplementary Cementitious Materials, ACI Mater. J., 116 (2019) 205-216.

[8] D. Glosser, A. Choudhary, O.B. Isgor, W.J. Weiss, Investigation of Reactivity of Fly Ash and Its Effect on Mixture Properties, ACI Materials Journal, 116 (2019) 193-200.

[9] D. Glosser, O.B. Isgor, W.J. Weiss, Non-Equilibrium Thermodynamic Modeling Framework for Ordinary Portland Cement/Supplementary Cementitious Material Systems, ACI Mater. J., 117 (2020) 111-123.

[10] D. Glosser, V. Jafari Azad, P. Suraneni, O.B. Isgor, W.J. Weiss, An extension of the Powers-Brownyard model to pastes containing SCM, ACI Mater. J., 116 (2019) 205-216.

[11] D. Glosser, P. Suraneni, O.B. Isgor, W.J. Weiss, Estimating reaction kinetics of cementitious pastes containing fly ash, Cem. Concr. Compos., 112 (2020) 103655.

[12] D. Glosser, P. Suraneni, O.B. Isgor, W.J. Weiss, Using glass content to determine the reactivity of fly ash for thermodynamic calculations, Cement Concrete Comp, 115 (2021).

[13] V. Jafari Azad, A.R. Erbektas, C. Qiao, O.B. Isgor, W.J. Weiss, Relating the formation factor and chloride binding parameters to the apparent chloride diffusion coefficient of concrete, ASCE Journal of Materials and Civil Engineering, (2018).

[14] P. Suraneni, V.J. Azad, O.B. Isgor, J. Weiss, Role of Supplementary Cementitious Material Type in the Mitigation of Calcium Oxychloride Formation in Cementitious Pastes, J. Mater. Civ. Eng., 30 (2018).

[15] P. Suraneni, V.J. Azad, O.B. Isgor, W.J. Weiss, Use of Fly Ash to Minimize Deicing Salt Damage in Concrete Pavements, Transp Res Record, (2017) 24-32.

[16] EPRI, Performance-Based Mixture Proportioning of Concrete Incorporating Off-Spec Fly Ash: Mixture Proportioning Method Development and Validation, EPRI, Palo Alto, CA, 2020, pp. 78.

1 Introduction

The chemical compositions and reactivities of typical commercial and novel SCMs are listed in Table 1 to Table 8 in the following sections. The SCMs listed in the following subsections include: silica fume (specified in ASTM C1240 [17] / AASHTO M307 [18]), Class-F and Class-C fly ashes (specified in ASTM C618 [19] / AASHTO M295 [20]), off-spec fly ash (fly ash not conforming to ASTM C618 [19] specifications), bottom ash, slag (specified in ASTM C989 [21]), calcined clays, and pumices. A summary of the chemical composition and reactivity statistics of all SCMs is also provided in a tabulated form in Table 9 for quick reference. The chemical compositions are listed as the weight fractions of SiO_2, Al_2O_3, Fe2O3, CaO, Na_2O, K_2O, MgO, and SO_3. The DOR* of the SCMs, the maximum degree of pozzolanic reactivity, is also listed where available. Any blank cells in the tables indicate that the original source did not provide the data or the data could not be retrieved from the original source document.

The data was obtained from testing at Oregon State University [1-16]. Some of the published data in the literature were received in the electronic format from some sources such as the University of Miami [22, 23]. The chemical composition was obtained using X-Ray Fluorescence [24] and the reactivity was obtained using the Pozzolanic Reactivity Test (PRT) [25].

The PRT is performed by mixing the SCM with an excess of calcium hydroxide (SCM:$Ca(OH)_2$ = 1:3 by mass) and an excess of alkaline pore solution (0.5N KOH; (SCM+$Ca(OH)_2$):liquid = 0.90 by mass) [25, 26]. The cumulative heat released by the SCM is measured using an isothermal calorimeter for 10-days and the maximum degree of reactivity of the SCM (DOR*) is calculated by dividing the measured heat released by the theoretical maximum heat release by an SCM of its type [25], which is 804J/g_{SCM} for siliceous materials (silica fume, fly ashes, bottom ashes, pumices), 889J/g_{SCM} for calcareous materials (slags), and 699J/g_{SCM} for aluminous materials (calcined clays). If the R3 test [27, 28] was used to determine a relative reactivity, an estimate of the reactivity was obtained using the correction factor from [26], which can be used to estimate a numerical value of reactivity from the relative reactivity measurements in the R3 test.

2 Dataset

2.1 Silica fume

The data for un-densified and densified silica fume and their references are provided in Table 1. The DOR* is calculated using a practical simplification to the PRT [25].

Table 1. Chemical composition and DOR* of silica fume obtained from the literature

Reference	SiO_2	Al_2O_3	Fe_2O_3	CaO	Na_2O (# is Na_2O_{eq})	K_2O	MgO	SO_3	LOI	DOR*
Un-densified silica fume										
[29]	91.47	0.88	1.80	1.06	0.29	0.76	2.43			52%
[22]	93.47	0.00	0.02	0.00	0.00	0.00	0.00	0.00	3.82	79%
[30]	95.00	0.50	2.10	0.80	0.10	0.10				53%
[31]	91.62	0.51	0.03	3.43	0.34	0.37	0.25			72%
[26]	95.88	0.69	0.12	0.70	0.26	0.49	0.26	0.15	4.30	80%
[23]	97.3			0.00	0.00		0.06		1.35	59%
[23]	95.04			0.01	1.79		0.38		1.39	77%
[23]	74.95			17.9	0.52		2.89		0.89	88%
Densified silica fume										
[22]	91.47	0.88	0.00	1.60	0.29	0.76	2.43	0.25	0.67	52%
[23]	93.26			0.00	1.24		0.21		3.93	40%
[23]	97.21			0.00	0.16		0.15		1.61	63%
[23]	96.06			0.00	0.12		0.14		2.73	54%
[23]	93.65			0.10	0.23		0.37		4.47	52%
[23]	97.42			1.27	0.01		0.09		0.93	42%
[24]	95.88	0.69	0.12	0.70	0.16	0.49	0.26	0.15	4.30	78%

2.2 Fly ash, Class-F

The data for the chemical composition and the DOR* of Class-F fly ashes and their references are provided in Table 2.

Table 2. Chemical composition and DOR* of Class-F fly ashes obtained from the literature

Reference	SiO_2	Al_2O_3	Fe_2O_3	CaO	Na_2O	K_2O	MgO	SO_3	LOI	DOR*
[29]	52.77	19.72	4.81	14.23	0.79	1.08	3.19			39%
[29]	37.82	20.36	5.29	15.48	8.11	0.76	3.58			34%
[29]	55.70	23.71	3.75	10.50	2.46	0.81	1.00			41%
[29]	49.70	24.20	4.70	12.90	1.00	0.60	3.30			34%
[29]	41.62	21.30	8.14	17.13	1.01	1.49	2.84			34%
[29]	56.73	19.93	5.83	10.20	0.63	1.35	2.95			43%
[29]	49.94	23.90	4.42	13.34	0.92	0.54	3.28			42%

[29]	59.92	24.09	6.59	3.77	1.32	1.08	1.16			39%
[29]	53.14	23.31	13.25	3.28	0.93	2.62	1.01			26%
[32]	56.84	18.58	10.16	5.49	1.21	2.71	1.47			34%
[32]	41.62	21.30	8.14	17.13	1.01	1.49	2.84			43%
[32]	56.73	19.93	5.83	10.20	0.63	1.35	2.95			42%
[32]	49.94	23.90	4.42	13.34	0.92	0.54	3.28			39%
[32]	59.92	24.09	6.59	3.77	1.32	1.08	1.16			26%
[32]	53.14	23.31	13.25	3.28	0.93	2.62	1.01			42%
[22]	56.76	20.51	6.21	9.74	0.69	1.35	2.59			38%
[22]	55.70	23.71	3.75	10.50	2.46	0.81	1.00			40%
[22]	41.62	21.30	8.14	17.13	1.01	1.49	0.84			43%
[31]	55.41	25.46	8.33	7.94	0.70	1.41	1.77			38%
[33]	56.01	21.71	12.98	4.82	0.30	2.57	1.03			36%
[33]	58.70	25.70	3.70	9.00			1.10			39%
[34]	46.31	16.50	6.01	13.79	2.40	0.00	5.05	0.93	2.34	20%
[35, 36]	66.02	15.72	10.39	1.92	1.52	1.12	1.01	0.38	21.02	38%
[35, 36]	57.61	24.18	9.84	0.75	0.34	2.02	0.67	0.05	17.63	55%
[35, 36]	51.88	22.29	15.15	2.77	0.95	2.50	1.01	0.43	1.30	50%
[35, 36]	53.11	22.49	11.96	2.80	1.59	2.28	1.22	0.31	6.88	48%
[8]	42.25	14.20	4.98	13.66	2.92	1.46	4.48	0.79	0.78	41%
[8]	37.82	20.36	5.29	15.48	8.11	0.76	3.58	2.84	3.88	40%
[8]	52.77	19.72	4.81	14.23	0.79	1.08	3.19	0.87	1.04	62%
[8]	56.73	19.93	5.83	10.20	0.63	1.35	2.95	0.34	0.68	69%
[8]	49.94	23.90	4.42	13.34	0.92	0.54	3.28	0.70	0.82	64%
[8]	59.92	24.09	6.59	3.77	1.32	1.08	1.16	0.35	0.50	26%
[8]	51.88	22.29	15.15	2.77	0.95	2.50	1.01	1.01	1.30	60%
[8]	53.14	23.31	13.25	3.28	0.93	2.62	1.01	0.86	0.14	78%
[26]	51.86	21.70	5.04	8.61	2.58	1.45	2.58	0.78	1.42	36%
[24]	47.15	16.57	5.88	12.54	3.65	1.72	4.80	0.60	2.43	45%
[37, 38]	47.34	22.34	15.08	6.38	0.60	1.23	0.82	1.43	2.73	
[37, 38]	61.50	20.52	4.29	8.68	0.17	0.60	1.70	0.19	0.08	
[37, 38]	50.92	23.64	4.62	13.63	3.38	0.59	0.86	0.23	0.42	
[37, 38]	45.66	21.42	5.53	12.34	7.82	0.96	2.76	0.84	0.35	
[37, 38]	51.56	22.90	4.58	15.15	2.60	0.30	1.16	0.28	0.35	
[37, 38]	40.68	21.19	4.50	15.87	8.14	0.49	3.54	2.18	0.53	
[37, 38]	44.29	20.96	5.23	17.51	1.13	0.84	4.21	2.13	1.14	
[39]	70.80	24.40	2.20	0.10	0.70		0.20	0.00		29%[b]
[40]	61.30	19.40	4.50	9.10	0.30	1.06	2.30	0.20	0.10	20%[b]
[41]	59.10	20.20	8.85	3.36	0.34	1.87	1.17	0.12	0.96	43%[b]
[42, 43]	50.90	24.70	7.30	3.70	0.90	3.90	1.80	0.40	3.50	28%[b]
[38, 44]	38.13	20.99	5.46	15.54	7.88	0.77	3.71	2.90		
[38, 44]	35.88	18.00	6.68	25.84	1.87	0.44	6.14	1.84		
[38, 44]	56.72	20.29	5.62	9.95	0.54	1.38	2.97	0.51		
[38, 44]	52.02	16.38	4.39	18.68	0.75	0.92	2.86	0.90		
[45]	57.60	21.90	2.70	7.80	1.05		1.68	7.05		41%

[a] denotes the Na_2O_{eq} content, as these references provide Na_2O_{eq} without providing Na_2O and K_2O separately;
[b] denotes values that were obtained using techniques other than the PRT.

2.3 Fly Ash, Class-C

The data for the chemical composition and the DOR* of Class-C fly ashes and their references are provided in Table 3.

Table 3. Chemical composition and DOR* of Class-C fly ashes obtained from the literature

Reference	SiO_2	Al_2O_3	Fe_2O_3	CaO	Na_2O	K_2O	MgO	SO_3	LOI	DOR*
[29]	32.15	18.04	5.01	32.38	1.58	0.40	7.46			34%
[29]	32.98	16.43	5.82	27.92	1.67	0.39	6.91			25%
[29]	39.13	18.14	6.01	23.68	1.54	0.58	5.01			35%
[29]	37.26	18.96	6.26	24.00	1.69	0.58	5.14			24%
[29]	38.34	19.44	6.22	21.61	1.61	0.63	5.21			38%
[29]	38.05	19.32	5.64	22.68	1.80	0.46	5.55			32%
[29]	31.62	21.26	6.29	27.89	2.00	0.39	6.63			36%
[29]	35.59	19.01	5.56	25.73	1.51	0.47	4.66			44%
[29]	35.48	18.36	5.27	20.38	6.69	0.81	4.09			41%
[29]	37.34	22.48	5.45	21.30	1.50	0.56	4.08			42%
[32]	39.10	20.00	6.20	22.30	1.80	0.70	4.90			39%
[32]	36.20	19.90	6.70	24.00	1.70	0.50	5.20			39%
[32]	37.90	19.50	5.70	22.90	2.00	0.50	5.60			41%
[32]	33.20	17.00	5.80	28.10	1.90	0.40	7.00			40%
[32]	37.60	23.20	5.50	21.80	1.70	0.60	4.20			47%
[32]	38.40	19.80	6.20	21.90	1.80	0.60	5.30			47%
[32]	52.00	16.40	4.40	18.70	0.80	0.90	2.90			46%
[32]	44.23	16.93	5.75	22.92	1.16	0.34	4.39			42%
[22]	35.48	18.36	5.27	20.38	6.69	0.81	4.09			40%
[35, 36]	42.31	16.82	6.97	21.21	1.11	0.43	4.20	0.44	2.49	21%
[35, 36]	35.56	16.60	12.25	21.33	0.95	1.40	1.45	5.84	8.95	53%
[35, 36]	40.06	16.77	6.22	21.15	1.08	0.46	4.32	0.78	1.11	10%
[8]	38.05	19.32	5.64	22.68	1.80	0.46	5.55	0.86	2.82	44%
[8]	39.13	18.14	6.01	23.68	1.54	0.58	5.01	0.92	2.44	46%
[8]	38.34	19.44	6.22	21.61	1.61	0.63	5.21	1.29	2.66	48%
[8]	37.66	19.97	6.89	21.51	1.31	0.59	4.57	0.70	0.45	44%
[8]	37.34	22.48	5.45	21.30	1.50	0.56	4.08	0.95	3.27	58%
[8]	32.98	16.43	5.82	27.92	1.67	0.39	6.91	1.83	3.36	25%
[8]	37.26	18.96	6.26	24.00	1.69	0.58	5.14	1.13	2.34	24%
[39]	42.30	19.80	8.20	20.70	1.80[a]		2.20	1.40		21%[b]
[37]	39.77	21.46	5.69	18.46	3.71	0.66	3.77	1.86	1.06	
[37]	32.71	19.02	5.76	18.85	8.28	0.68	4.30	4.81	1.18	
[37]	38.42	20.57	5.64	20.50	2.64	0.62	4.39	1.76	2.01	

[37]	39.83	19.56	5.54	21.53	1.55	0.60	4.62	2.14	1.68	
[37]	38.22	18.43	5.72	24.61	1.39	0.44	4.72	1.55	0.18	
[37]	35.20	18.72	6.06	26.61	1.59	0.36	5.12	2.49	0.39	
[37]	36.12	18.64	6.07	26.62	1.34	0.40	5.41	1.80	0.16	
[37]	34.60	16.45	7.13	27.71	1.51	0.21	5.89	2.71	0.28	
[37]	31.65	16.65	7.28	29.10	1.72	0.20	6.57	3.17	0.36	
[37]	41.12	11.24	5.93	30.00	1.10	1.76	4.40	2.13	0.78	
[44]	39.13	20.37	6.15	21.18	1.60	0.65	5.33	1.37		
[44]	36.21	19.94	6.67	23.96	1.67	0.52	5.17	1.44		
[44]	38.34	19.87	6.12	23.07	1.53	0.62	5.16	1.14		
[44]	38.71	18.82	5.88	23.12	1.78	0.58	5.55	1.27		
[44]	34.47	20.35	5.65	26.50	1.76	0.46	4.70	1.71		
[44]	36.36	17.44	6.08	25.68	1.90	0.46	6.15	2.03		
[44]	35.88	18.00	6.68	25.84	1.87	0.44	6.14	1.84		
[44]	52.02	16.38	4.39	18.68	0.75	0.92	2.86	0.90		

[a] denotes the Na_2O_{eq} content, as these references provide Na_2O_{eq} without providing Na_2O and K_2O separately;

[b] denotes values that were obtained using techniques other than the PRT.

2.4 Fly ash, Off-spec

The data for the chemical composition and the DOR* of off-spec fly ashes (fly ashes not conforming to ASTM C618) and their references are provided in Table 4. In addition to the data from the literature, the last 15 rows of Table 4 contain DOR* data for off-spec ashes tested by [32] for which the chemical composition was unavailable at the time of writing (denoted by the superscript ‘c’ in the table).

Table 4. Chemical composition and DOR* of off-spec fly ashes obtained from the literature

Reference	**SiO_2**	**Al_2O_3**	**Fe_2O_3**	**CaO**	**Na_2O (# is Na_2O_{eq})**	**K_2O**	**MgO**	**SO_3**	**LOI**	**DOR***
[35, 36]	35.56	16.60	12.25	21.33	0.95	1.40	1.45	5.84	8.95	53%
[35, 36]	28.35	14.75	4.78	28.51	1.16	0.42	4.33	11.76	3.67	42%
[35, 36]	28.91	14.82	4.67	27.33	1.09	0.54	3.78	11.90	3.22	57%
[35, 36]	24.98	17.31	5.48	29.07	1.75	0.43	6.73	6.73	19.07	38%
[35, 36]	21.88	17.42	5.70	29.21	1.67	0.47	7.00	5.03	3.03	28%
[35, 36]	66.02	15.72	10.39	1.92	1.52	1.12	1.01	0.38	21.02	38%
[35, 36]	57.61	24.18	9.84	0.75	0.34	2.02	0.67	0.05	17.63	55%
[35, 36]	53.11	22.49	11.96	2.80	1.59	2.28	1.22	0.31	6.88	48%
[39]	70.80	24.40	2.20	0.10	0.70	-	0.20	0.00	-	29%[b]
[39]	42.30	19.80	8.20	20.70	1.80	-	2.20	1.40	-	21%[b]
[45]	57.60	21.90	2.70	7.80	1.05		1.68	7.05		41%[b]
[46]	26.60	12.80	5.40	29.70	1.60	--.4	5.50	12.40	2.50	
[47]	18.96	13.96	5.93	22.37	--	--	--	5.40	16.35	

[48]	46.47		1.08	18.52	--	--	0.18	0.03	18.97	
[49]	19.80	13.00	6.00	9.80	--	--	3.10	11.80	0.70	
[50]	24.23	15.27	3.89	42.25	0.36	0.51	0.74	6.77	1.20	
[51]	8.00	7.00	2.30	9.40	--	--	2.20	--	49.00	
[52]	24.00	15.00	6.00	25.80	--	--	5.30	--	12.00	
[53]	21.40	13.90	3.20	38.60	1.20	0.10	2.40	15.00	--	
[54]	37.50	10.50	33.50	5.50	1.00	0.90	5.00	6.50	--	
[54]	30.00	14.50	37.00	5.00	0.45	0.75	4.00	7.00	--	
[54]	34.50	16.00	31.00	5.50	0.55	1.35	3.00	6.00	--	
[46]	35.10	17.50	3.40	12.30	1.20	0.60	3.20	1.40	22.80	
[55]	45.10	23.10	3.16	7.80	--	--	--	--	13.40	
[55]	50.80	26.90	5.50	0.70	--	--	--	--	10.70	
[55]	34.90	24.40	12.60	3.20	--	--	--	--	20.50	
[52]	35.60	18.00	3.50	3.20	--	--	1.00	--	34.00	
[56]	40.10	32.10	14.70	0.60	--	--	1.50	--	16.00	
[51]	36.07	19.90	3.60	2.90	--	--	1.06	--	32.40	
[57]	39.20	29.80	5.00	6.20	--	--	--	--	12.10	
[58]	27.30	16.30	5.90	23.70	--	--	1.80	6.40	5.40	
[59]	43.16	16.27	3.62	16.83	0.70	3.58	1.86	5.08	--	
[54]	34.50	19.00	31.00	3.25	0.60	0.90	4.00	6.50	--	
[60]	41.90	21.50	12.70	13.90	2.70	2.50	2.60	0.60	0.70	
[61]	26.10	16.15	8.74	23.97	2.84	0.63	4.92	2.82	9.20	
[56]	31.10	18.30	6.10	23.10			5.60	3.70	0.98	
[54]	49.50	17.00	10.00	7.50	0.50	2.25	2.25	5.00		
[56]	45.10	27.10	3.20	1.07			0.60		6.20	
[32]										32%[c]
[32]										37%[c]
[32]										41%[c]
[32]										42%[c]
[32]										38%[c]
[32]										44%[c]
[32]										36%[c]
[32]										44%[c]
[32]										40%[c]
[32]										47%[c]
[32]										40%[c]
[32]										43%[c]
[32]										43%[c]
[32]										41%[c]
[32]										38%[c]

[a] denotes the Na_2O_{eq} content, as these references provide Na_2O_{eq} without providing Na_2O and K_2O separately;
[b] denotes values that were obtained using techniques other than the PRT;
[b] denotes fly ashes whose DOR* was available but their chemical composition was unavailable at the time of writing.

2.5 Bottom Ash

The data for the chemical composition of bottom ashes and their references are provided in Table 5. While the reactivity data from the literature for bottom ashes is very sparse, recent laboratory testing [35, 36, 62] has revealed that bottom ashes typically have a reactivity about 15% lower than Class-F fly ashes. However, more testing is required to confirm this finding.

Table 5. Chemical composition and DOR* of bottom ashes obtained from the literature

Reference	SiO_2	Al_2O_3	Fe_2O_3	CaO	Na_2O	K_2O	MgO	SO_3	LOI
[63]	38.80	21.30	12.10	16.50	1.00	2.50	1.70	2.40	2.90
[64]	54.60	8.00	8.50	11.10		1.30	1.50		
[65]	45.30	18.10	19.84	8.70		2.48	0.97	0.35	
[66]	47.53	20.69	5.99	4.17	0.33	0.76	0.82	1.00	
[67]	56.00	26.70	5.80	0.80	0.20	2.60	0.60	0.10	4.60
[68]	54.50	15.40	11.16	4.69		1.34	4.26	1.30	8.90
[69]	41.70	17.10	6.63	22.50	1.38	0.40	4.91	0.42	1.13
[69]	61.80	17.80	6.97	3.19	0.95	2.00	1.34	0.79	3.61
[69]	57.90	22.60	6.50	2.00	0.08	0.60	3.20		2.40
[69]	60.70	18.30	6.56	3.25	0.89	2.12	1.28	0.82	4.13
[69]	56.00	26.70	5.80	0.80	0.20	2.60	0.60	0.10	4.60
[69]	54.80	28.50	8.49	4.20	0.08	0.45	0.35		2.46
[69]	57.76	21.58	8.56	1.58	0.14	1.08	1.19	0.02	
[69]	47.53	20.69	5.99	4.17	0.33	0.76	0.82	1.00	
[69]	52.10	18.34	11.99	6.61	2.43	1.57	4.85		4.13
[69]	62.32	27.21	3.57	0.50	0.70	2.58	0.95		
[69]	45.30	18.10	19.84	8.70		2.48	0.69	0.30	0.10
[69]	55.10	28.10	8.30	1.10		1.50	0.30	0.30	3.90
[69]	58.70	20.10	6.20	9.50	0.10	1.00	1.60	0.40	0.80
[69]	52.20	27.50	6.00	5.90	1.30	0.60	1.70		1.80
[69]	34.00	36.00	16.80	2.40		5.90			
[69]	48.00	20.10	8.77	7.11			3.13		8.10
[69]	59.82	27.76	3.77	1.86	1.61	0.33	0.70	1.39	4.69
[69]	52.50	17.65	8.30	4.72			0.58		4.01
[69]	50.49	27.56	10.93	4.19	0.57	0.82	1.24	0.10	1.11
[69]	66.90	17.70	6.50	1.56			0.51		2.65
[69]	47.10	23.10	5.70	7.80	0.70	5.30	1.50	1.50	2.52
[69]	44.10	9.21	24.30	13.00		1.25	1.88		

[a] denotes the Na_2O_{eq} content, as these references provide Na_2O_{eq} without providing Na_2O and K_2O separately;
[b] denotes values that were obtained using techniques other than the PRT.

2.6 Slag

The data for the chemical composition and the DOR* of slags and their references are provided in Table 6.

Table 6. Chemical composition and DOR* of slags obtained from the literature

Reference	SiO_2	Al_2O_3	Fe_2O_3	CaO	Na_2O	K_2O	MgO	SO_3	LOI	DOR*
[32, 70]	16.15	4.31	27.03	41.03	0.20	0.17	3.64			24%
[29]	29.78	12.18	1.22	46.54	0.45	0.41	6.00			56%
[29]	32.59	13.94	0.78	42.22	0.23	0.37	4.96			50%
[29]	34.56	10.46	0.70	39.13	0.31	0.44	10.68			49%
[29]	35.32	10.64	0.51	45.06	0.39	0.56	6.29			45%
[29]	36.80	8.37	0.96	41.86	0.28	0.39	10.24			47%
[29]	37.71	8.23	0.74	39.08	0.25	0.43	10.89			43%
[29]	41.01	9.26	0.66	39.73	0.30	0.43	12.19			44%
[22]	32.59	13.94	0.78	42.22	0.23	0.37	4.96	2.02	2.08	50%
[22]	34.56	10.46	0.70	39.13	0.31	0.44	10.68	1.11	1.79	49%
[22]	37.71	8.23	0.74	39.08	0.25	0.43	10.89	1.07	0.75	43%
[22]	41.01	9.26	0.66	39.73	0.30	0.43	12.19	1.05	0.00	44%
[31]	32.71	15.12	0.53	39.92	0.38	0.58	6.50			58%
[33]	32.09	12.88	0.75	42.44	0.13	0.27	6.53			58%
[38, 71]	37.60	3.30	0.40	17.60	0.22	0.34	11.20	1.94	0.00	
[38, 72]	35.58	9.40	0.79	40.88	0.16	0.38	10.92	1.23	1.34	
[73]	36.10	9.90	0.79	41.00	0.18	0.35	9.50	0.30	0.60	60%[b]
[73]	33.00	11.80	1.60	41.30	0.32	0.51	9.00	0.13	0.80	75%[b]
[73]	35.00	12.30	0.60	40.90	0.64	0.83	7.80	0.30	0.20	
[73]	35.40	12.70	0.30	41.30	0.24	0.60	6.70	0.14	0.60	65%[b]
[73]	36.80	11.20	0.40	40.00	0.35	0.47	7.70	0.13	0.60	
[73]	33.60	13.40	1.50	40.40	0.33	0.52	8.30	0.05	0.40	
[73]	31.00	16.00	1.50	36.30	0.56	0.65	11.00	0.16	0.40	
[74]	36.84	9.53	1.11	36.92	0.52[a]		11.07	0.10	0.00	
[75]	35.28	9.71	0.56	40.47	0.41	0.45	8.76	3.79	0.00	
[76]	33.88	9.56	0.78	40.90	0.70[a]		11.40	3.08		
[77]	36.80	10.30	0.70	36.50	0.37	0.44	12.60	0.24	0.00	
[78]	36.10	10.10	0.53	35.00	0.48	0.35	14.20	3.63	1.72	

[a] denotes the Na_2O_{eq} content, as these references provide Na_2O_{eq} without providing Na_2O and K_2O separately;
[b] denotes values that were obtained using techniques other than the PRT.

2.7 Calcined Clays

The data for the chemical composition and the DOR* of calcined clays and their references are provided in Table 7.

Table 7. Chemical composition and DOR* of calcined clays obtained from the literature

Reference	SiO_2	Al_2O_3	Fe_2O_3	CaO	Na_2O	K_2O	MgO	SO_3	LOI	DOR*
[22]	51.92	43.10	1.52	0.14	0.05	0.23	0.15	0.11		91%
[22]	61.82	27.78	3.35	0.33	0.22	3.27	0.38	0.11		47%
[31]	57.71	36.70	2.44	1.46	0.00	0.65	0.48			67%
[33]	51.50	44.05	1.40	0.11	0.05	0.18	0.15			64%
[79]	45.82	38.79	0.56	0.01	0.20	0.03	0.05			66%[b]
[79]	46.24	40.03	0.27	0.03	0.02	0.03	0.04			62%[b]
[79]	44.77	38.45	1.12	0.02	0.01	0.05	0.06			66%[b]
[79]	44.85	38.62	0.17	0.04			0.04			67%[b]
[79]	58.03	19.60	4.08	0.02	3.04	0.04	2.36		12.74	25%[b]
[79]	57.72	16.92	1.49	3.31	0.06	0.03	5.82		14.41	29%[b]
[79]	52.62	0.46	0.34	2.28	0.15	0.09	23.67		20.48	15%[b]
[79]	52.62	22.63	6.64	0.12	0.48	7.72	2.32		6.68	14%[b]
[80]	54.93	39.75	4.16	0.06	0.18	0.17	0.02	0.10	0.24	
[27]	52.00	43.80	0.30		0.30	0.10		0.10		
[27]	51.80	42.40	1.90	0.10	0.10	0.10	0.10			
[27]	50.80	42.70	0.60			0.10				
[27]	44.90	32.30	15.40	1.30	0.40	0.20	0.80	0.10		
[27]	54.70	26.80	13.60	0.30		0.40	1.00			
[27]	67.60	22.60	6.10	0.50		0.30				
[27]	68.40	17.50	8.90	0.60	0.10	2.30	0.70			
[32]	48.90	22.80	0.20	0.00	8.40		10.00	0.00		82%

[a] denotes the Na_2O_{eq} content, as these references provide Na_2O_{eq} without providing Na_2O and K_2O separately;
[b] denotes values that were obtained using techniques other than the PRT.

2.8 Pumice

Table 8 shows the chemical compositions of pumices obtained from the literature. While the reactivity data from the literature for pumices is very sparse, recent laboratory testing [62] has revealed that pumices in general have a similar reactivity to Class-F fly ashes. However, more testing is required to confirm this finding.

Table 8. Chemical composition of pumices obtained from the literature

Reference	SiO_2	Al_2O_3	Fe_2O_3	CaO	Na_2O	K_2O	MgO	SO_3	LOI
[81]	60.82	16.71	7.04	4.44	5.42	2.25	1.94	0.14	1.52
[82]	77.52	12.99	1.50	0.10	0.12	0.95	0.40	0.52	5.42
[83]	69.42	12.42	1.08	0.94	3.81	5.16	0.44	0.04	4.40
[84]	69.00	13.00	1.00	0.96	4.00	4.90	0.45	0.05	4.00
[84]	69.00	12.00	1.20	1.40	5.10	4.40	0.33	0.05	4.40
[85]	72.00	12.00	2.00	0.70	4.00	5.00	0.10	0.20	-
[86]	55.40	16.40	4.64	1.70	5.33	5.46	0.62	-	8.78

[87]	69.40	12.40	1.10	0.94	3.80	5.20	0.44	0.04	3.10
[88]	43.90	17.90	13.00	7.98	5.13	2.91	5.47	0.08	-
[89]	69.09	10.63	1.01	0.93	2.49	4.77	0.09	-	5.27
[89]	69.16	10.79	1.00	0.93	2.13	5.08	0.16	-	5.40
[89]	69.75	11.18	1.04	0.97	2.34	4.79	0.25	-	5.91
[90]	72.14	12.81	1.25	0.84	2.38	4.09	0.19	0.02	5.04
[91]	45.75	12.72	8.93	11.00	4.72	3.11	8.01	0.89	0.28
[91]	44.10	13.29	11.75	10.37	4.43	2.55	9.19	0.20	0.13
[92]	68.58	11.89	1.16	4.11	2.77	4.02	0.44	-	-
[93]	69.78	11.16	2.11	2.47	4.33	2.87	0.60	0.06	4.66
[94]	63.57	14.81	6.75	2.66	4.36	4.36	1.02	0.02	4.59
[95]	65.74	16.72	3.58	3.33	4.48	3.05	0.95	0.65	2.40
[96]	43.90	14.80	12.60	9.50		0.00	8.90	-	7.50
[97]	68.70	14.80	2.30	-		0.00	0.50	-	5.60
[98]	65.74	15.89	2.54	3.35	4.97	1.92	1.33	-	3.43
[99]	58.20	28.70	3.24	6.01		-	1.61	0.44	1.86
[100]	51.80	22.10	7.30	6.20	-	-	8.30	-	0.40
[101]	61.20	18.10	7.40	4.90	3.90	2.50	1.80	0.11	1.40
[102]	63.57	14.81	6.75	2.66		0.00	1.02	-	4.59
[103]	69.66	14.65	2.58	2.20	4.04	2.44	0.48	0.02	3.31
[103]	66.99	13.42	2.38	5.70	3.88	2.41	0.79	-	3.95
[103]	65.00	15.73	3.96	5.66	-	1.83	0.93	-	2.91
[104]	61.99	15.58	4.91	1.41	6.21	4.81	0.19	0.08	4.27
[104]	62.27	15.70	4.94	1.18	6.09	4.63	0.18	0.09	4.31
[105]	47.40	18.57	10.04	7.90	1.07	2.58	6.04	0.34	2.21
[106]	63.40	18.45	3.10	5.44	3.00	2.06	1.50	-	2.88
[107]	87.40	10.52	0.17	-	0.13	0.10	0.13	0.00	-

[a] denotes the Na_2O_{eq} content, as these references provide Na_2O_{eq} without providing Na_2O and K_2O separately.

3 Statistical summary

Table 9 provides a statistical summary of the data presented in this document.

Table 9. Combined statistics of the chemical composition and DOR* all SCMs shown in this document.

Stat	SiO_2	Al_2O_3	Fe_2O_3	CaO	Na_2O	K_2O	MgO	SO_3	LOI	DOR*
Un-densified silica fume										
Mean	91.84	0.52	0.81	2.99	0.41	0.34	0.90	0.08	2.35	70%
St. Dev.	6.66	0.29	0.93	5.73	0.55	0.27	1.13	0.08	1.42	13%
Max	97.30	0.88	2.10	17.90	1.79	0.76	2.89	0.15	4.30	88%
Min	74.95	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.89	52%
Densified silica fume										
Mean	94.99	0.79	0.06	0.52	0.32	0.63	0.52	0.20	2.66	54%
St. Dev.	2.07	0.10	0.06	0.63	0.39	0.14	0.78	0.05	1.49	12%
Max	97.42	0.88	0.12	1.60	1.24	0.76	2.43	0.25	4.47	78%
Min	91.47	0.69	0.00	0.00	0.01	0.49	0.09	0.15	0.67	40%
Class-F fly ash										
Mean	51.97	21.47	7.01	9.94	1.88	1.34	2.27	1.05	2.89	42%
St. Dev.	7.43	2.57	3.37	5.61	2.17	0.78	1.33	1.33	5.09	12%
Max	70.80	25.70	15.15	25.84	8.14	3.90	6.14	7.05	21.02	78%
Min	35.88	14.20	2.20	0.10	0.17	0.00	0.20	0.00	0.08	20%
Class-C fly ash										
Mean	37.75	18.73	6.11	23.54	1.98	0.58	4.94	1.80	1.90	38%
St. Dev.	4.04	2.00	1.11	3.16	1.45	0.26	1.17	1.15	1.93	10%
Max	52.02	23.20	12.25	32.38	8.28	1.76	7.46	5.84	8.95	58%
Min	31.62	11.24	4.39	18.46	0.75	0.20	1.45	0.44	0.16	10%
Off-spec fly ash										
Mean	36.69	18.50	9.11	14.00	1.19	1.16	2.79	5.46	13.16	41%
St. Dev.	13.32	5.27	8.92	11.69	0.66	0.89	1.89	4.14	11.34	8%
Max	70.80	32.10	37.00	42.25	2.84	3.58	7.00	15.00	49.00	57%
Min	8.00	7.00	1.08	0.10	0.34	0.10	0.18	0.00	0.70	21%
Bottom ash										
Mean	52.27	21.50	9.28	5.81	0.72	1.77	1.60	0.72	3.43	
St. Dev.	7.50	5.94	5.03	5.05	0.63	1.36	1.29	0.63	2.15	
Max	66.90	36.00	24.30	22.50	2.43	5.90	4.91	2.40	8.90	
Min	34.00	8.00	3.57	0.50	0.08	0.33	0.30	0.02	0.10	
Slag										
Mean	34.56	10.59	1.73	39.52	0.32	0.45	9.17	1.14	0.66	47%
St. Dev.	4.37	2.77	4.88	4.84	0.12	0.13	2.64	1.22	0.66	8%
Max	41.01	16.00	27.03	46.54	0.64	0.83	14.20	3.79	2.08	58%
Min	16.15	3.30	0.30	17.60	0.13	0.17	3.64	0.05	0.00	24%
Calcined clays										
Mean	53.32	31.32	3.55	0.56	0.81	0.84	2.67	0.09	10.91	70%

St. Dev.	6.64	11.53	4.26	0.88	2.02	1.82	5.67	0.04	6.91	15%
Max	68.40	44.05	15.40	3.31	8.40	7.72	23.67	0.11	20.48	91%
Min	44.77	0.46	0.17	0.00	0.00	0.03	0.02	0.00	0.24	47%
Pumice										
Mean	63.57	14.81	4.28	3.72	3.73	3.13	1.91	0.19	3.80	N/A
St. Dev.	9.80	3.60	3.59	3.03	1.56	1.68	2.77	0.24	1.98	N/A
Max	87.40	28.70	13.00	11.00	6.21	5.46	9.19	0.89	8.78	N/A
Min	43.90	10.52	0.17	0.10	0.12	0.00	0.09	0.00	0.13	N/A

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