

**SULPHATE ATTACK RESISTANCE OF
MORTAR CONTAINING SPENT
BLEACHING EARTH ASH**



**FACULTY OF ENGINEERING
UNIVERSITI MALAYSIA SABAH
2023**

**SULPHATE ATTACK RESISTANCE OF MORTAR
CONTAINING SPENT
BLEACHING EARTH ASH**

RAIHANA FARAHIYAH BINTI ABD RAHMAN



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**THIS IS SUBMITTED IN FULFILMENT OF
THE REQUIREMENTS FOR THE DEGREE OF
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ABSTRACT

In this study, the spent bleaching earth ash (SBEA) was used as partial cement replacement to determine its effects on the sulphate resistance of mortar. Sulphate attack resistance of concrete containing SBEA has been studied previously and acknowledged to enhance the sulphate resistance of concrete. However, the knowledge on the effect of particle size and level of replacement of SBEA on sulphate attack resistance of mortar is still limited. The physical, chemical, mineralogical and microstructural properties of unground spent bleaching earth ash (USBEA) and ground spent bleaching earth ash (GSBEA) were characterized by using laser particle analysis, X-ray fluorescence (XRF), X-diffraction (XRD), and scanning electron microscope (SEM). The use of USBEA and GSBEA as cement replacement at 10, 20, 30, 40, and 50% were prepared for mortar mixture in this study. The pozzolanic activity of SBEA was evaluated through strength activity index (SAI) test at 7, 28, and 90 days. The effect of USBEA and GSBEA on the expansion of mortar bar after being immersed in 5% sodium sulphate solution was evaluated according to ASTM C1012 by measuring the length change of mortar bars at 1, 2, 3, 4, 8, 13, 15 weeks and subsequent length change was measured at 4 and 6 months. The grinding process of GSBEA resulted in smaller particle size ($704 \text{ m}^2/\text{kg}$) and higher specific surface area than USBEA ($390 \text{ m}^2/\text{kg}$). It was found that 40% of GSBEA showed the highest SAI with 135.16% and 136.17% at 28 and 90 days compared to other specimens. The expansion of mortar bar containing 40% GSBEA also showed the lowest expansion value (0.01%) at 6 months. Lower amount of calcium hydroxide (CH) was determined on mortar containing 40% GSBEA showing that it was consumed through pozzolanic reaction to form additional calcium silicate hydrate (CSH). Based on the SEM analysis, CSH was found in mortar containing 40% of GSBEA. This study also discovered that replacing cement with 40% of GSBEA reduced the expansion of mortar due to sulphate attack. Therefore, 40% of GSBEA as partial cement replacement has the potential to improve the sulphate resistance of mortar.

ABSTRAK

KETAHANAN SERANGAN SULFAT MORTAR YANG MENGANDUNGI SPENT BLEACHING EARTH ASH

Dalam kajian ini, spent bleaching earth ash (SBEA) digunakan sebagai pengganti separa simen untuk menentukan kesannya terhadap rintangan sulfat mortar. Rintangan serangan sulfat konkrit yang mengandungi SBEA telah dikaji sebelum ini dan diakui boleh meningkatkan rintangan sulfat konkrit. Walau bagaimanapun, pengetahuan tentang kesan saiz zarah dan tahap penggantian SBEA terhadap rintangan serangan sulfat mortar masih terhad. Sifat fizikal, kimia, mineralogi dan mikrostruktur unground spent bleaching earth ash (USBEA) dan ground spent bleaching earth ash (GSBEA) telah dicirikan dengan menggunakan analisis zarah laser, pendarfluor sinar-X (XRF), pembelauan-X (XRD), dan pengimbasan mikroskop elektron (SEM). Penggunaan USBEA dan GSBEA sebagai pengganti simen pada 10, 20, 30, 40, dan 50% telah disediakan untuk campuran mortar dalam kajian ini. Aktiviti pozzolanik SBEA dinilai melalui ujian indeks aktiviti kekuatan (IAK) pada 7, 28, dan 90 hari. Kesan USBEA dan GSBEA pada pengembangan bar mortar selepas direndam dalam larutan natrium sulfat 5% dinilai mengikut ASTM C1012 dengan mengukur perubahan panjang bar mortar pada 1, 2, 3, 4, 8, 13, 15 minggu dan perubahan panjang seterusnya diukur pada 4 dan 6 bulan. Proses pengisaran GSBEA menghasilkan saiz zarah yang lebih kecil ($704 \text{ m}^2/\text{kg}$) dan luas permukaan spesifik yang lebih tinggi daripada USBEA ($390 \text{ m}^2/\text{kg}$). Didapati 40% GSBEA menunjukkan IAK tertinggi iaitu 135.16% dan 136.17% pada 28 dan 90 hari berbanding spesimen lain. Pengembangan bar mortar yang mengandungi 40% GSBEA juga menunjukkan nilai pengembangan yang paling rendah (0.01%) pada 6 bulan. Jumlah kalsium hidroksida (CH) yang lebih rendah ditentukan pada mortar yang mengandungi 40% GSBEA menunjukkan bahawa ia telah digunakan melalui tindak balas pozzolanik untuk membentuk kalsium silikat hidrat (CSH) tambahan. Berdasarkan analisis SEM, CSH didapati dalam mortar yang mengandungi 40% GSBEA. Kajian ini juga mendapati bahawa menggantikan simen dengan 40% GSBEA mengurangkan pengembangan mortar akibat serangan sulfat. Oleh itu, 40% GSBEA sebagai pengganti simen separa berpotensi untuk meningkatkan rintangan sulfat mortar.

LIST OF CONTENTS

	Page
TITLE	i
DECLARATION	ii
CERTIFICATION	iii
ACKNOWLEDGEMENT	iv
ABSTRACT	v
<i>ABSTRAK</i>	vi
LIST OF CONTENTS	vii
LIST OF TABLES	xii
LIST OF FIGURES	xiv
LIST OF SYMBOLS	xvii
LIST OF ABBREVIATIONS	xviii
LIST OF APPENDICES	xx
CHAPTER 1: INTRODUCTION	
1.1 Overview	1
1.2 Background of the Study	3
1.2.1 Sulphate Attack	3
1.2.2 Effect of Pozzolan	6
1.3 Problem Statement	8
1.4 Significance of Study	9
1.5 Aims and Objectives of Study	10
1.6 Scope of Study	11
1.7 Thesis Layout	12

CHAPTER 2: LITERATURE REVIEW

2.1	Introduction	13
2.2	Cement	14
2.3	Pozzolan as a Partial Cement Replacement	16
2.4	Role of Pozzolans	20
2.4.1	Role of Palm Oil Fuel Ash	20
2.4.2	Role of Rice Hush Ash	23
2.4.3	Role of Coal Ash	25
2.4.4	Role of Waste Glass Powder	28
2.5	Spent Bleaching Earth Ash	30
2.5.1	Role of Waste Glass Powder	30
2.5.2	Spent Bleaching Earth Ash as Cement Replacement	33
2.6	Mortar	38
2.7	Concrete	40
2.8	Effect of Pozzolan on the Properties of Mortar	41
2.8.1	Pozzolanic Activity	42
2.8.2	Water Absorption and Sorptivity of Mortar	46
2.9	Sulphate attack	47
2.9.1	Internal Sulphate Attack	47
2.9.2	External Sulphate Attack	48
2.9.3	Chemical Sulphate Attack	49
2.9.4	Physical Sulphate Attack	55
2.10	Methods to Prevent Sulphate Attack	56
2.11	Sulphate Attack Resistance Influence Factors	57
2.11.1	Chemical Composition of Pozzolan	57
2.11.2	Level of Replacement of Pozzolan	59
2.11.3	Particle Size of Pozzolan	63
2.12	Effects of Pozzolans on the Sulphate Attack Resistance	65
2.12.1	Expansion of Mortar Bars against Sulphate Attack	66

2.12.2	Microanalyses of Deterioration Products	70
2.12.3	Compressive Strength against Sulphate Attack	81
2.13	Chapter Summary	87

CHAPTER 3: METHODOLOGY

3.1	Introduction	89
3.2	Materials and Apparatus	91
3.3	Testing on Raw Materials	94
3.3.1	Chemical Properties	94
3.3.2	X-Ray Diffraction Analysis	94
3.3.3	Scanning Electron Microscope	95
3.3.4	Particle Size Analysis and Specific Surface Area	96
3.3.5	Moisture Content and Loss on Ignition	97
3.3.6	Specific Gravity	98
3.4	Properties of Mortar	99
3.4.1	Flow Table Test	100
3.4.2	Water Requirement	101
3.4.3	Strength Activity Index	102
3.4.4	Water Absorption	103
3.4.5	Sorptivity Test	103
3.4.6	Microstructural Analysis	104
3.5	Sulphate Resistance of Mortar and Concrete	104
3.5.1	Preparation of Mortar Bar	107
3.5.2	Testing Procedure of Mortar Bar	109
3.5.3	Testing Procedure of Concrete	112
3.6	Chapter Summary	115

CHAPTER 4: CHARACTERIZATION OF UNGROUND AND GROUND SPENT BLEACHING EARTH ASH AND THEIR EFFECTS ON THE PROPERTIES OF MORTAR

4.1	Introduction	117
4.2	Characterization of Unground and Ground Spent Bleaching Earth Ash	118
4.2.1	Physical Properties	118
4.2.2	Chemical Properties	119
4.2.3	Mineralogical Properties	121
4.2.4	Microstructural Properties	122
4.3	Properties of Mortar Containing Unground and Ground Spent Bleaching Earth Ash	125
4.3.1	Pozzolanic Reactivity of Spent Bleaching Earth Ash	125
4.3.2	Water Absorption of Mortar	131
4.3.3	Sorptivity of Mortar	134
4.3.4	Microstructural Analysis	136
4.4	Chapter Summary	138

CHAPTER 5: SULPHATE ATTACK OF MORTAR CONTAINING UNGROUND AND GROUND SPENT BLEACHING EARTH ASH

5.1	Introduction	141
5.2	Expansion of Mortar Bar	142
5.3	Microstructural Characterization of Hydration Product	149
5.3.1	Scanning Electron Microscope Equipped with Energy Dispersive X-ray	149
5.3.2	X-Ray Diffraction	159
5.3.3	Thermogravimetric Analysis	163
5.4	Application of SBEA in Concrete Exposed to Sulphate Attack	166
5.4.1	Workability of Concrete	167

5.4.2	Compressive Strength of Concrete	167
5.4.3	Strength Deterioration Factor	170
5.4.4	Water Absorption of Concrete	171
5.4.5	Volume Permeable Void of Concrete	172
5.4.6	Microstructural Analysis of Concrete	174
5.5	Chapter Summary	179
CHAPTER 6: CONCLUSION AND RECOMMENDATION FOR FUTURE RESEARCH		
6.1	Introduction	182
6.2	Conclusion	182
6.2.1	Characterization of Physical, Chemical, Mineralogical and Microstructural Properties of Ground and Unground SBEA	182
6.2.2	Effect of Unground and Ground Spent Bleaching Earth Ash on Properties of Mortar	183
6.3.3	The Suitable Level of Replacement of Ground and Unground SBEA as a Partial Cement Replacement in Resisting External Sulphate Attack in terms of Expansion of Mortar	183
6.3	Recommendation for Future Research	185
REFERENCES		186
APPENDICES		200

LIST OF TABLES

	Page
Table 2.1 : Major Mineral Composition of Cement	15
Table 2.2 : Survey Variables	19
Table 2.3 : Chemical Composition Requirement (ASTM C618)	34
Table 2.4 : Previous Studies on Spent Bleaching Earth Ash	37
Table 2.5 : Pozzolanic activity of SBEA and other Pozzolans in terms of Strength Activity Index	44
Table 2.6 : R factor and Sulphate Resistance Relationship	50
Table 2.7 : Recent Studies on The Sulphate Resistance of Mortar and Concrete containing Pozzolan	66
Table 2.8 : Expansion of Mortar Bar after being immersed in 5% Sodium Sulphate Solution for 6 Months (ASTM C1012)	69
Table 2.9 : Previous Studies on the Microstructural Analyses	74
Table 2.10 : Main Products from Sulphate Attack Reaction Based on Previous Studies	79
Table 2.11 : Previous Studies on the Effect of SBEA and Other Pozzolans on the Compressive Strength of Concrete against Sulphate Attack	86
Table 3.1 : Chemical Composition of OPC	91
Table 3.2 : Mixture Proportion of Mortar	99
Table 3.3 : Details of Mortar Specimen	100
Table 3.4 : Testing Methods for Sulphate Resistance	106
Table 3.5 : Maximum Expansion Limit of Mortar Bar after being Immersed in a 5% Sodium Sulphate Solution (Na_2SO_4)	107
Table 3.6 : Maximum Expansion Limit of Mortar Bar containing Pozzolan after being Immersed in a 5% Sodium Sulphate Solution (Na_2SO_4)(ASTM C618)	107
Table 3.7 : Mixture Proportion of Mortar Bar	108
Table 3.8 : Mix Design of Concrete (kg/cm^3)	113
Table 3.9 : Details of Concrete Specimen	113
Table 4.1 : Physical Properties of Materials	119
Table 4.2 : Chemical Properties of Materials	121
Table 4.3 : Micrograph Images of Materials	124
Table 4.4 : Water Requirement and Flow of Mortar Specimens	126
Table 4.5 : Increment of Strength Activity Index of USBEA and GSBEA	130

Table 5.1	: R factor and CaO/SiO ₂ of USBEA and GSBEA	143
Table 5.2	: Length Change of Mortar Bar containing USBEA	145
Table 5.3	: Length Change of Mortar Bar containing GSBEA	146
Table 5.4	: Workability of Concrete	167
Table 5.5	: Water Absorption of Concrete Specimen	171



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LIST OF FIGURES

	Page
Figure 2.1 : Production of Spent Bleaching Earth	32
Figure 2.2 : Flow chart of Spent Bleaching of Earth Ash (SBEA) Production	33
Figure 2.3 : SEM image of SBEA	35
Figure 2.4 : Formation of Ettringite	52
Figure 2.5 : Concrete Lining of the Tunnel Deteriorated due to Sulphate Attack	55
Figure 2.6 : SEM Image of OPC Sample against Sulphate Attack	73
Figure 2.7 : Interfacial Transition Zone and Bulk Cement Paste in Concrete	84
Figure 3.1 : Flow Chart of Methodology	90
Figure 3.2 : (a) USBEA and (b) GSBEA	92
Figure 3.3 : Planetary Grinding Ball Mill	93
Figure 3.4 : X-ray Diffraction Equipment (Rigaku)	95
Figure 3.5 : SEM-EDX (Hitachi S3400N)	96
Figure 3.6 : Laser Particle Size Analyzer (LPSA-MASTERSIZER 3000)	97
Figure 3.7 : Flow Table Test Equipment	101
Figure 3.8 : Mortar Bar Mould	108
Figure 3.9 : Length Comparator	110
Figure 3.10 : pH Meter	110
Figure 3.11 : Thermogravimetric Analyzer	112
Figure 4.1 : XRD Patterns of OPC, USBEA, and GSBEA	122
Figure 4.2 : Water Requirement of Mortar Specimens	127
Figure 4.3 : Strength Activity Index of USBEA and GSBEA Mortars	131
Figure 4.4 : Water Absorption of Mortar Specimens at 28 days	133
Figure 4.5 : Water Absorption of Mortar Specimens at 90 days	133
Figure 4.6 : Sorptivity of Mortar Specimens at 28 days	135
Figure 4.7 : Sorptivity of Mortar Specimens at 90 days	135

Figure 4.8	: Micrograph Image of Mortar Paste of Control at 90 days	137
Figure 4.9	: Micrograph Image of Mortar Paste of USBEA40 at 90 days	137
Figure 4.10	: Micrograph Image of Mortar Paste of GSBEA40 at 90 days	138
Figure 5.1	: Expansion of Mortar Bars containing USBEA	145
Figure 5.2	: Expansion of Mortar Bars containing GSBEA	146
Figure 5.3	: Comparison of Expansion of Mortar Bars	148
Figure 5.4	: Micrograph Image of Control Specimen at 4 Months	150
Figure 5.5	: Micrograph Image of Control Specimen at 6 Months	151
Figure 5.6	: Micrograph Image of USBEA40 at 4 Months	153
Figure 5.7	: Micrograph Image of USBEA40 at 6 Months	154
Figure 5.8	: Micrograph Image of GSBEA40 at 4 Months	155
Figure 5.9	: Micrograph Image of GSBEA40 at 6 Months	156
Figure 5.10	: Micrograph Image of Void in Mortar Specimens at 6 months; (a) Control, (b) USBEA40, and (c) GSBEA40	157
Figure 5.11	: XRD Patterns of Control after being immersed in 5% Sodium Sulphate Solution for 4 Months	160
Figure 5.12	: XRD Patterns of Control after being immersed in 5% Sodium Sulphate Solution for 6 Months	161
Figure 5.13	: XRD Patterns of USBEA40 after being immersed in 5% Sodium Sulphate Solution for 4 Months	161
Figure 5.14	: XRD Patterns of USBEA40 after being immersed in 5% Sodium Sulphate Solution for 6 Months	162
Figure 5.15	: XRD Patterns of GSBEA40 after being immersed in 5% Sodium Sulphate Solution for 4 Months	162
Figure 5.16	: XRD Patterns of GSBEA40 after being immersed in 5% Sodium Sulphate Solution for 6 Months	163
Figure 5.17	: TGA Curve Results of the Mortar Pastes prepared using OPC, USBEA40, and GSBEA40 after 4 Months being immersed in a 5% Sodium Sulphate Solution	165

Figure 5.18	: TGA Curve Results of the Mortar Pastes prepared using OPC, USBEA40, and GSBEA40 after 6 Months being immersed in a 5% Sodium Sulphate Solution	165
Figure 5.19	: Weight Loss of CH of Mortar Specimens at 4 and 6 Months after being immersed in a 5% Sodium Sulphate Solution	166
Figure 5.20	: Compressive Strength of Concrete Specimens at 28 days	168
Figure 5.21	: Compressive Strength of Concrete Specimens at 90 days	169
Figure 5.22	: Strength Deterioration Factor of Concrete Specimen	170
Figure 5.23	: Influence of SBEA Water Absorption Capacities	172
Figure 5.24	: Volume of Permeable Void of Concrete	174
Figure 5.25	: Micrograph Image of ITZ of CONTROL Concrete	175
Figure 5.26	: Micrograph Image of ITZ of USBEA40 Concrete	176
Figure 5.27	: Micrograph Image of ITZ of GSBEA40 Concrete	176
Figure 5.28	: Micrograph Image of CONTROL Concrete	177
Figure 5.29	: Micrograph Image of USBEA40 Concrete	178
Figure 5.30	: Micrograph Image of GSBEA40 Concrete	178

LIST OF SYMBOLS

%	-	Percentage
°C	-	Degree Celcius
θ	-	Theta
g	-	Gram
L	-	Liter
ml	-	Mililiter
m/kg²	-	Meter per square kilogram
mm	-	Milimeter
min	-	Minute
μm	-	Micrometer
MPa	-	Megapascal

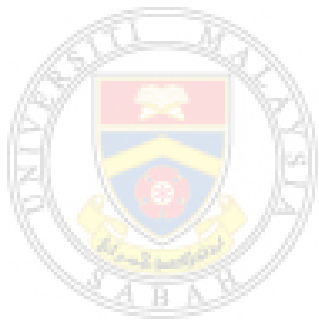


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LIST OF ABBREVIATIONS

Al₂O₃	-	Aluminium oxide
ASTM	-	American Society for Testing and Materials
BS	-	British Standard
C	-	Calcite
Ca	-	Calcium
CaO	-	Calcium oxide
CH	-	Calcium hydroxide
C₂S	-	Dicalcium silicate
C₃A	-	Tricalcium aluminate
C₄AF	-	Tetracalcium aluminoferrite
CSH	-	Calcium silicate hydrate
Et. al	-	And others
Fe₂O₃	-	Iron oxide
LOI	-	Loss on ignition
OPC	-	Ordinary Portland Cement
Q	-	Quartz
SAI	-	Strength activity index
SBEA	-	Spent bleaching earth ash
SDF	-	Strength deterioration factor
SEM	-	Scanning electron microscope
SiO₂	-	Silicon oxide
SO₃	-	Sulfur trioxide
TGA	-	Thermogravimetric analyzer

- UMS** - Universiti Malaysia Sabah
- UTM** - Universiti Teknologi Malaysia
- XRD** - X-ray diffraction
- XRF** - X-ray Fluorescence



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LIST OF APPENDICES

	Page
Appendix A : Specific Gravity	200
Appendix B : Expansion Values of Mortar Bar	201
Appendix C : DTA Curves of Mortar Pastes after being Immersed in 5% Sodium Sulphate Solution	205
Appendix D : Lists of Publications	206



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CHAPTER 1

INTRODUCTION

1.1 Overview

Over the past decades, the reuse of waste products from the palm oil industry has been applied to achieve a more sustainable environment. These waste products are usually sent to landfills and cause environmental problems due to the degradation of substances contained in the wastes. The palm oil industry generates wastes that cause major disposal problems. Malaysia is known as one of the largest producers of palm oil among several countries, such as Indonesia and Thailand, throughout the world (Kamil & Omar, 2016).

In a palm oil refinery, bleaching earth is used to remove the dark colour and other impurities of crude palm oil. Bleaching earth is a fine clay powder that mainly consists of silicon oxide (Loh et al., 2013; E. Y. Park et al., 2004). The estimated amount of bleaching earth used in refinery plants is around 600,000 metric tonnes or more based on the production of more than 60 million tonnes of palm oil worldwide (Kaimal et al., 2002; Loh et al., 2013). After the phase of bleaching and degumming of crude palm oil, the residual waste, which is also called spent bleaching earth (SBE), is generated (Loh et al., 2013). In that process, bleaching earth absorbs just about 0.5% by weight of oil (Kheang et al., 2007). Dumping of SBE waste at landfills could lead to fire and pollution hazards (Loh et al., 2013). It might be due to the degradation of the residual oil as well as metallic contaminants and organic compounds in the SBE waste (O. Rokiah et al., 2019).

Over 2 million tonnes per year of SBE is generated by the palm oil industry globally (Beshara & Cheeseman, 2014). In Malaysia, approximately 240 000 tonnes of SBE have been generated annually from the palm oil refinery plant (Loh et al., 2017; O. Rokiah et al., 2019). It is challenging to manage SBE waste due to its large volume generated from the refinery plant. Due to the insufficient solutions to reuse or recycle for beneficial use, SBE is usually disposed of at landfills improperly and without treatment. Disposing of by-products from the industry at landfills may also cause environmental problems such as greenhouse effects (Loh et al., 2013). Besides that, it requires a high cost to dump SBE into landfills (Kheang et al., 2007). Therefore, SBE should be reused and recycled in the industry for better waste management.

Despite being discarded in landfills, SBE is extracted to produce residual oil and de-oiled SBE. Several researchers have used the residual oil to develop solutions for its disposal problem by recycling SBE into useful material, such as the application of SBE to produce biodiesel (Kheang, Loh Soh et al., 2010; Kheang et al., 2007) and non-food application such as soap (Daous & Al-Zahrani, 2000; Kheang, Loh Soh et al., 2010). Apart from the recovery of residual oil, de-oiled SBE is also the product of the extraction process of SBE. De-oiled SBE is obtained after the oil from the SBE wastes is recovered. It has been used in clay blocks (Beshara & Cheeseman, 2014; Eliche-Quesada & Corpas-Iglesias, 2014). Furthermore, de-oiled spent bleaching earth (SBE) is calcined at high temperatures to produce a spent bleaching earth ash (SBEA), which is also referred to as eco-processed pozzolan in various studies (Kho, 2021; Kusaimi et al., 2020; Yunus et al., 2019). It has also been mentioned as a processed SBE by Othman et al. (2019b) and Wei Chong et al. (2021). SBEA has been utilized as a partial replacement for cement in a mortar (Wei Chong et al., 2021) and concrete in studies conducted by Kho (2021), Othman et al. (2020), and Yunus et al. (2020).

Based on the previous studies, it appears that using SBEA as a partial cement replacement in concrete can effectively improve its resistance against sulphate attack (Othman et al., 2020; Yunus et al., 2020), chloride attack (Yunus et al., 2020), and acid attack (Othman et al., 2019a). Sulphate attack is a common cause of concrete