Ultrasonic Pulse Transmission Tests: Datasets — Test Series 4, Cement Paste at Early Stages

Jakob Harden[†]
[†]Graz University of Technology, Graz, Austria

Corresponding author email: jakob.harden@tugraz.at

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Abstract

The test series was created to receive information about the impact of the behaviour of the piezoelectric shear wave sensor on the measurement results of ultrasonic transmission tests performed on cement pastes at early stages. The approach for the test series was to vary the parameters water-cement-ratio and pulse-width. This results in a two-dimensional test parameter grid (water-cement-ratio versus pulse-width). Tests were performed for each grid point in order to receive information needed to optimize the pulse width for the shear wave sensors, but also a possible dependency between material behaviour and pulse-width. The materials tested were blends from ordinary Portland cement and tap water. The test methods used were ultrasonic pulse transmission method with combined compression- and shear wave measurements, gravimetric density tests (fresh paste density, solid specimen density) and hydration temperature tests. All test data and metadata are summarized into datasets using GNU Octave's open binary file format.

1 Introduction

This document provides a technical description of the datasets of a series of ultrasonic pulse transmission tests (UPTT) performed in the course of the PhD thesis of the author of this document (see title page). The test series has been performed to receive information about the behaviour of cement pastes at early stages (within the first 24 hours). The design of this test series is based on the variation of two different parameters. The water-cement-ratio $w/c = [0.40, 0.45, 0.50, 0.55, 0.60]$ and the pulse-width $W = [2.5, 7.5, 10.0, 12.5]$ μsec. This results in a two-dimensional test parameter grid. For each grid point $(w/c, W)$, tests were carried out using a distance between actuator and sensor of $D = 50$ mm. For comparison reasons, additional tests ($D = 25$ mm, $W = 10.0$ μsec, all water-cement-ratios mentioned before) were performed. The result is a collection of 29 datasets containing the measurement data of the UPTTs and additional subsidiary tests performed along with the UPTTs (fresh paste density, solid sample density, environment temperature, specimen temperature). The test device used for the UPTTs is the FreshCon[1] device (developed at the University of Stuttgart, Germany) equipped with the V101-RB sensor (resonance frequency $f_r = 500$ kHz) for the compression wave measurements and the V1548-RB sensor (resonance frequency $f_r = 500$ kHz) for the shear wave measurements. Both sensors manufactured by Olympus IMS[2]. The materials used for the cement paste blends are ordinary Portland cement[3] (CEM I 42.5 N) and tap water. Beside the measurement results, an elaborate description of devices, materials, mixtures and test operation procedures is available in the data set structure. This record is published to allow other researchers to make use of it. In particular, those not having access to the required laboratory facilities and test equipment. To allow others to make use of these datasets freely, an open license was chosen by the author (Creative Commons 4.0 Attribution, CC-BY-4.0).

2 Record content

The repository record consists of the following three files:

- **ts4_techdescr.pdf** contains the technical description (this file).
- **ts4_rawdata.tar.xz** contains the raw measurement data. This compressed TAR archive consists of a set of ZIP archives enlisted in table 8 in section **Appendix - Tables**. The content of the ZIP archives is described in section 3.

- **ts4_datasets.tar.xz** contains the datasets compiled from the raw measurement data. This compressed TAR archive consists of a set of binary files (*.oct, open GNU octave binary format) enlisted in table 9 in section **Appendix - Tables**. The structure of the content of each data set is described in section 4 in detail.

Extracting data set files from compressed TAR archives: Under Linux the content of the compressed TAR archives can easily be extracted with the command line tool "tar"[4] on the "bash"[5] command prompt. On Microsoft Windows one may use "7zip"[6] instead.

```
$ tar -xf <filename>.tar.xz
```

Data integrity: To ensure the integrity of the files contained in the compressed TAR archives, the SHA256 checksum is also provided along with the files. See second column in tables 8 and 9 in section **Appendix - Tables**. Check the integrity of a file with "sha256sum"[7] at the "bash" command prompt.

```
$ echo "<sha256_checksum> <filename>" > checkfile.txt
$ sha256sum --check checkfile.txt
```

File name convention, data set code: The variation of the parameters w/c-ratio and pulse-width but also the distance between actuator and sensor is reflected in the file names. The file names are a concatenation of the test series id <T>, the water-cement-ratio <W>, the distance between the actuator and sensor <D> in millimetres and the pulse-width <P> in μsec. Filename structure: **<T>_wc<W>_d<D>_w<P>.oct**. As example, a test performed on a cement paste with a water-cement ratio of 0.40, a distance between actuator and sensor of $50mm$ and a pulse-width of 10.0 μsec is stored in **ts4_wc040_d50_w100.oct**. The name of the corresponding raw data archive is **ts4_wc040_d50_w100.zip**. Here it is to mention, that some test were carried out twice. That is denoted in the file names with the suffix `_a`.

3 Raw data archive structure

Each data set in the raw data archive **ts4_rawdata.tar.xz** is represented by a ZIP archive. The directories and files contained in the archive files are enlisted in table 3.

L	C	Path	Type	Description
0	1	<datasetcode>	directory	data set directory
1	1	projinfo.txt	plain text file	metadata and information about additional tests
1	1	Channel 1	directory	compression wave measurement data
2	1	../measurements.txt	plain text file	list of signal filenames and recording timestamp
2	1	../settings.txt	plain text file	device and measurement settings
2	1	../tst.tem	plain text file	temperature data (if exists)
2	N	../tst<num>.dat	plain text files	signal data of compression wave measurements
1	1	Channel 2	directory	shear wave measurement data
2	1	../measurements.txt	plain text file	list of signal filenames and recording timestamp
2	1	../settings.txt	plain text file	device and measurement settings
2	1	../tst.tem	plain text file	temperature data (if exists)
2	N	../tst<num>.dat	plain text files	signal data of shear wave measurements

Table 1: Raw data directory- and file structure (ZIP archives). L . . . directory level; C . . . cardinality.

4 Data set binary file structure

Each data set in the data set archive **ts4_datasets.tar.xz** is represented by a OCT file (<filename>.oct). They were generated from raw data consisting of plain text files (see also 3). Therefore, GNU Octave 6.2.0[8]

command scripts were used. The result of the conversion process are datasets available in GNU Octave's open binary file format. The data in the datasets is organized in a C-like hierarchical data structure. That structure consists of several structural levels. The top structural level serves to classify the data according to individual thematic areas. The metadata and data of the measurement results are stored in the lower structure levels. To be able to display the data and metadata as simply as possible, sub-structures are used, which are referred to here as "atomic elements" and represent the lowest structural level of the data. There are three defined types of atomic elements: the atomic reference element (ARE), the atomic attribute element (AAE) and the atomic data element (ADE). All atomic elements consist of simple structure fields that hold the data.

4.1 Atomic elements

Atomic reference element (ARE): Atomic reference elements are used to link objects to each other. This is to avoid copies of recurring content (e.g. for a specimen used in several subsidiary tests). They consist of a set of fields enlisted in table 2.

Field	Description	Data type
obj	object type (always "ARE")	string
ver	version number [major, minor]	uint16
t	tag, a descriptive name	string
i	referenced id	uint, [uint]
r	referenced object name	{string}
d	description	string

Table 2: Field list of atomic reference elements (ARE)

Atomic attribute element (AAE): Atomic attribute elements are used to store text only (e.g. additional description of the parent data structure). They consist of a set of fields enlisted in table 3.

Field	Description	Data type
obj	object type (always "AAE")	string
ver	version number [Major, Minor]	[uint16]
t	tag, a descriptive name	string
v	value, text	string, {string}
d	description	string

Table 3: Field list of atomic attribute elements (AAE)

Atomic data element (AAE): Atomic data elements are used to store values in combination with value type and physical unit (e.g. measurement data). They consist of a set of fields enlisted in table 4. The value type enumerators stored in field "vt" are enlisted in table 6 in section **Appendix - Tables**.

Field	Description	Data type
obj	object type (always "ADE")	string
ver	version number [Major, Minor]	[uint16]
t	tag, a descriptive name	string
vt	value type enumerator	string
v	value of given value type	depends on value type
u	unit	string
d	description	string

Table 4: Field list of atomic data elements (ADE)

4.2 Data set structure hierarchy

The hierarchy of the data structure consists of top-level substructures containing various atomic elements or other lower-level substructures (e.g. ds.tst, test collection). A list of main substructures is shown in table 5. A more detailed description of the structure hierarchy is shown in table 7 in section **Appendix - Tables**.

L	C	Path	Description
0	1	ds	structure root
1	1	ds.meta_ser	test series metadata
1	1	ds.meta_set	data set metadata
1	N	ds.loc	geo-location information, GPS coordinates
1	1	ds.lic	license information
1	N	ds.aut	author information
1	N	ds.dev	test device information
1	N	ds.mat	test material information
1	1	ds.rec	mixture/blend recipe definition
1	1	ds.mix	mixture component information
1	N	ds.spm	test specimen information, specimen I and II
1	1	ds.tst	test collection
2	1	ds.tst.s01	fresh paste density
2	1	ds.tst.s02	solid specimen density, specimen I
2	1	ds.tst.s03	solid specimen density, specimen II
2	1	ds.tst.s04	ultrasonic measurement distance, specimen I
2	1	ds.tst.s05	ultrasonic measurement distance, specimen II
2	1	ds.tst.s06	ultrasonic pulse transmission test (compression wave), specimen I
2	1	ds.tst.s07	ultrasonic pulse transmission test (shear wave), specimen II
2	1	ds.tst.s08	specimen temperature, specimen II
2	1	ds.tst.s09	environment temperature

Table 5: Main substructures. L . . . hierarchy level; C . . . cardinality.

4.3 Accessing items of the hierarchical data structure

To access the data and metadata in the hierarchical data structure, the file need to be loaded into memory first. Then, the structure handling commands of GNU Octave can be used to access single items. To illustrate the process, some typical application examples using the GNU Octave command line interface are given below.

Load data set: Load data set and store the result in variable `ds`.

```
octave: >>> ds = load('/path/to/dataset/file.oct', 'dataset').dataset;
```

Accessing items: The following commands store the signal data of all compression wave signals in variable `s1` and all shear wave signals in variable `s2`. All other elements can be accessed in the same way. A detailed list of available structure elements is shown in table 7 in section **Appendix - Tables**.

```
octave: >>> s1 = ds.tst.s06.d13.v;
octave: >>> s2 = ds.tst.s07.d13.v;
```

References

[1] Smartmote. *Smartmote - FreshCon*. July 14, 2023. URL: http://www.smartmote.de/joomla/de/produkte/~ultraschall/9-produkte/19-neptun-webservices-5.

[2] Evident. *Contact Transducers*. July 14, 2023. URL: https://www.olympus-ims.com/en/ultrasonic-transducers/contact-transducers/#!cms[focus]=cmsContent10862.

[3] Vereinigung der österreichischen Zemetindustrie | VÖZ. *Zementtype*. July 14, 2023. URL: https://www.zement.at/der-baustoff/zement/zementtype.

[4] die.net. *tar(1) - Linux man page*. July 14, 2023. URL: https://linux.die.net/man/1/tar.

[5] die.net. *bash(1) - Linux man page*. July 14, 2023. URL: https://linux.die.net/man/1/bash.

[6] www.7 zip.org. *7zip download*. July 14, 2023. URL: https://www.7-zip.org/download.html.

[7] die.net. *sha256sum(1) - Linux man page*. July 14, 2023. URL: https://linux.die.net/man/1/sha256sum.

[8] John W. Eaton et.al. *GNU Octave - Scientific Programming Language*. July 14, 2023. URL: `https://octave.org/`.

Appendix - Tables

Data type	Description
string	character array, character = 8 bit
string_arr	1D cell array (vector) of strings
string_mat	2D cell array (matrix) of string
boolean	unsigned integer, 8 bit
boolean_arr	1D array (vector) of type boolean
boolean_mat	2D array (matrix) of type boolean
uint	unsigned integer
uint_arr	1D array (vector) of type uint
uint_mat	2D array (matrix) of type uint
int	signed integer
int_arr	1D array (vector) of type int
int_mat	2D array (matrix) of type int
single	single precision floating point number, 32 bit
single_arr	1D array (vector) of type single
single_mat	2D array (matrix) of type single
double	double precision floating point value, 64 bit
double_arr	1D array (vector) of type double
double_mat	2D array (matrix) of type double

Table 6: Value types for atomic data elements (ADE)

Table 7: Detailed overview of the hierarchical structure of the datasets (*.oct files).

Path	Type	Tag	Description
ds	struct_dataset	—	**structure root**
ds.meta_ser	struct_metaser	—	**substructure**
ds.meta_ser.r01	ARE	author	author reference
ds.meta_ser.r02	ARE	license	license reference
ds.meta_ser.d01	ADE	series_id	test series id
ds.meta_ser.a01	AAE	series_code	test series code
ds.meta_ser.a02	AAE	series_name	test series name
ds.meta_ser.a03	AAE	description	test series description
ds.meta_ser.a04	AAE	abstract	test series abstract
ds.meta_ser.a05	AAE	context	test series context
ds.meta_ser.a06	AAE	date_start	test series start date
ds.meta_ser.a07	AAE	date_end	test series end date
ds.meta_set	struct_metaset	—	**substructure**
ds.meta_set.r01	ARE	author	author reference
ds.meta_set.r02	ARE	series	test series reference
ds.meta_set.r03	ARE	location	location reference
ds.meta_set.r04	ARE	license	license reference
ds.meta_set.d01	ADE	dataset_id	data set id
ds.meta_set.a01	AAE	dataset_code	data set code
ds.meta_set.a02	AAE	dataset_name	data set name
ds.meta_set.a03	AAE	description	description, general
ds.meta_set.a04	AAE	description_abstract	description, abstract
ds.meta_set.a05	AAE	description_methods	description, methods
ds.meta_set.a06	AAE	description_tableofcontents	description, tableofcontents
ds.meta_set.a07	AAE	created_by	data set creator name
ds.meta_set.a08	AAE	collected_by	data set collector name
ds.meta_set.a09	AAE	copyrighted_by	data set copyrighter name
ds.meta_set.a10	AAE	date_created	date created

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Path	Type	Tag	Description
ds.meta_set.a11	AAE	date_collected	date collected
ds.meta_set.a12	AAE	date_copyrighted	date copyrighted
ds.meta_set.a13	AAE	size	data set size, number of files
ds.meta_set.a14	AAE	format	data set file format
ds.meta_set.a15	AAE	version	data set version
ds.meta_set.a16	AAE	context	data set context
ds.meta_set.a17	AAE	rawdata_directory	data set rawdata directory
ds.meta_set.a18	AAE	rawdata_archive	data set rawdata archive
ds.loc	struct_loc	—	**substructure array**
ds.loc.d01	ADE	location_id	location id
ds.loc.d02	ADE	geolocation	geo location, latitude, longitude
ds.loc.a01	AAE	country	country
ds.loc.a02	AAE	state_province	state or province
ds.loc.a03	AAE	city	city
ds.loc.a04	AAE	zipcode	zip code, postal code
ds.loc.a05	AAE	street	street name
ds.loc.a06	AAE	housenumber	house number
ds.loc.a07	AAE	description	location description
ds.lic	struct_lic	—	**substructure**
ds.lic.r01	ARE	author	author reference
ds.lic.d01	ADE	license_id	license id
ds.lic.a01	AAE	license_code	license code
ds.lic.a02	AAE	rightsholder	rights holder
ds.lic.a03	AAE	rights	rights description, e.g. Creative Commons Attribution 4.0 International
ds.lic.a04	AAE	rights_uri	rights URI, e.g. https://spdx.org/licenses/CC-BY-4.0.html
ds.lic.a05	AAE	rights_identifier_scheme	rights identifier scheme, e.g. SPDX
ds.lic.a06	AAE	rights_identifier_scheme_uri	rights identifier scheme URI, e.g. https://spdx.org/licenses/
ds.lic.a07	AAE	license_description	license description
ds.lic.a08	AAE	spdx_icon	license icon (spdx)
ds.lic.a09	AAE	spdx_id	license id (spdx)

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Path	Type	Tag	Description
ds.aut	struct_aut	—	**substructure**
ds.aut.d01	ADE	author_id	author id
ds.aut.a01	AAE	name	full name
ds.aut.a02	AAE	givenname	given name, first name
ds.aut.a03	AAE	familyname	family name, surname
ds.aut.a04	AAE	initials	initials
ds.aut.a05	AAE	title_pfx	title before the name (prefix)
ds.aut.a06	AAE	title_sfx	title behind the name (suffix)
ds.aut.a07	AAE	organization	organization name
ds.aut.a08	AAE	department	department name
ds.aut.a09	AAE	role	role in organization/department
ds.aut.a10	AAE	country	country
ds.aut.a11	AAE	state_province	state or province
ds.aut.a12	AAE	city	city name
ds.aut.a13	AAE	zipcode	zip code, postal code
ds.aut.a14	AAE	street	street name
ds.aut.a15	AAE	email	email address
ds.aut.a16	AAE	name_identifier_type	name identifier type, e.g. ORCID
ds.aut.a17	AAE	name_identifier_type_uri	name identifier type uri, e.g. https://orcid.org/
ds.aut.a18	AAE	name_identifier	name identifier, e.g. ORCID id
ds.aut.a19	AAE	description	author description
ds.dev	struct_dev	—	**substructure array**
ds.dev.d01	ADE	device_id	device id
ds.dev.a01	AAE	name	device name
ds.dev.a02	AAE	vendor	vendor name
ds.dev.a03	AAE	product	product name
ds.dev.a04	AAE	category	device category
ds.dev.a05	AAE	usage	device usage
ds.dev.a06	AAE	description	device description
ds.dev.s01	ADE	data_array	device properties

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Path	Type	Tag	Description
ds.mat	struct_mat	—	**substructure array**
ds.mat.d01	ADE	material_id	material id
ds.mat.a01	AAE	name	material name
ds.mat.a02	AAE	vendor	vendor name
ds.mat.a03	AAE	product	product name
ds.mat.a04	AAE	category	material category
ds.mat.a05	AAE	description	material description
ds.mat.a06	AAE	storage_place	material storage place
ds.mat.a07	AAE	storage_condition	material storage condition
ds.rec	struct_rec	—	**substructure**
ds.rec.d01	ADE	recipe_id	recipe id
ds.rec.a01	AAE	recipe_code	recipe code
ds.rec.s01	struct_mix_component	—	mix components
ds.rec.s02	ADE	w/c-ratio	water-cement-ratio, mass of water divided by mass of cement
ds.mix	struct_mix	—	**substructure**
ds.mix.r01	ARE	author	author reference
ds.mix.r02	ARE	device	device reference
ds.mix.r03	ARE	recipe	recipe reference
ds.mix.r04	ARE	location	location reference
ds.mix.d01	ADE	mixture_id	mixture id
ds.mix.d02	ADE	datetime	date and time, seconds since epoch (UTC)
ds.mix.d03	ADE	mixing_time	mixing/blending time
ds.mix.d04	ADE	speed_level	mixer speed level
ds.mix.d05	ADE	agitator_speed	mixer agitator speed
ds.mix.d06	ADE	attachment_speed	mixer attachment speed
ds.mix.a01	AAE	operator	operator name
ds.mix.a02	AAE	procedure	procedure description
ds.mix.a03	AAE	description	general description
ds.spm	struct_spm_paste	—	**substructure array**
ds.spm.r01	ARE	author	author reference

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Path	Type	Tag	Description
ds.spm.r02	ARE	mixture	mixture reference
ds.spm.r03	ARE	device	device reference
ds.spm.r04	ARE	location	location reference
ds.spm.d01	ADE	specimen_id	specimen id
ds.spm.d02	ADE	datetime	date and time, seconds since epoch (UTC)
ds.spm.a01	AAE	specimen_code	specimen code
ds.spm.a02	AAE	operator	operator name
ds.spm.a03	AAE	procedure	procedure description
ds.spm.a04	AAE	description	general description
ds.tst	struct_test	—	**substructure**
ds.tst.s01	struct_test_fpd	—	**substructure**
ds.tst.s01.r01	ARE	author	author reference
ds.tst.s01.r02	ARE	mixture	mixture reference
ds.tst.s01.r03	ARE	device	device reference
ds.tst.s01.r04	ARE	location	location reference
ds.tst.s01.d01	ADE	datetime	date and time, seconds since epoch (UTC)
ds.tst.s01.d02	ADE	beaker_volume	beaker volume
ds.tst.s01.d03	ADE	gross_weight	gross weight, measurement result
ds.tst.s01.d04	ADE	beaker_weight	beaker weight, net weight, measurement result
ds.tst.s01.d05	ADE	specimen_weight	specimen weight, calculated value
ds.tst.s01.d06	ADE	specimen_density	specimen density, calculated value
ds.tst.s01.a01	AAE	testname	test name
ds.tst.s01.a02	AAE	operator	operator name
ds.tst.s01.a03	AAE	procedure	procedure description
ds.tst.s01.a04	AAE	calculation	calculation description, formula
ds.tst.s01.a05	AAE	description	general description
ds.tst.s02	struct_test_ssd1	—	**substructure**
ds.tst.s02.r01	ARE	author	author reference
ds.tst.s02.r02	ARE	specimen	specimen reference
ds.tst.s02.r03	ARE	device	device reference

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Path	Type	Tag	Description
ds.tst.s02.r04	ARE	location	location reference
ds.tst.s02.d01	ADE	datetime	date and time, seconds since epoch (UTC)
ds.tst.s02.d02	ADE	specimen_weight	specimen weight, measurement result
ds.tst.s02.d03	ADE	floating_specimen_weight	floating specimen weight, measurement result
ds.tst.s02.d04	ADE	water_temperature	water temperature of water basin, measurement result or estimation based on environment temperature
ds.tst.s02.d05	ADE	water_density	density of water in basin, calculated value
ds.tst.s02.d06	ADE	water_weight_displaced	weight of displaced water, calculated value
ds.tst.s02.d07	ADE	specimen_volume	specimen volume, calculated value
ds.tst.s02.d08	ADE	specimen_density	specimen density, calculated value
ds.tst.s02.a01	AAE	testname	test name
ds.tst.s02.a02	AAE	operator	operator name
ds.tst.s02.a03	AAE	procedure	procedure description
ds.tst.s02.a04	AAE	calculation	calculation description, formula
ds.tst.s02.a05	AAE	description	general description
ds.tst.s03	struct_test_ssd1	—	**substructure**
ds.tst.s03.r01	ARE	author	author reference
ds.tst.s03.r02	ARE	specimen	specimen reference
ds.tst.s03.r03	ARE	device	device reference
ds.tst.s03.r04	ARE	location	location reference
ds.tst.s03.d01	ADE	datetime	date and time, seconds since epoch (UTC)
ds.tst.s03.d02	ADE	specimen_weight	specimen weight, measurement result
ds.tst.s03.d03	ADE	floating_specimen_weight	floating specimen weight, measurement result
ds.tst.s03.d04	ADE	water_temperature	water temperature of water basin, measurement result or estimation based on environment temperature
ds.tst.s03.d05	ADE	water_density	density of water in basin, calculated value
ds.tst.s03.d06	ADE	water_weight_displaced	weight of displaced water, calculated value
ds.tst.s03.d07	ADE	specimen_volume	specimen volume, calculated value
ds.tst.s03.d08	ADE	specimen_density	specimen density, calculated value
ds.tst.s03.a01	AAE	testname	test name
ds.tst.s03.a02	AAE	operator	operator name

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Path	Type	Tag	Description
ds.tst.s03.a03	AAE	procedure	procedure description
ds.tst.s03.a04	AAE	calculation	calculation description, formula
ds.tst.s03.a05	AAE	description	general description
ds.tst.s04	struct_test_umd1	—	**substructure**
ds.tst.s04.r01	ARE	author	author reference
ds.tst.s04.r02	ARE	specimen	specimen reference
ds.tst.s04.r03	ARE	device	device reference
ds.tst.s04.r04	ARE	location	location reference
ds.tst.s04.d01	ADE	datetime	date and time, seconds since epoch (UTC)
ds.tst.s04.d02	ADE	total_distance	total distance, measurement result
ds.tst.s04.d03	ADE	spacer_thickness	thickness of spacer disks, steel washer, measurement result
ds.tst.s04.d04	ADE	specimen_thickness	distance between actuator and sensor, calculated value
ds.tst.s04.a01	AAE	testname	test name
ds.tst.s04.a02	AAE	operator	operator name
ds.tst.s04.a03	AAE	procedure	procedure description
ds.tst.s04.a04	AAE	calculation	calculation description, formula
ds.tst.s04.a05	AAE	description	general description
ds.tst.s05	struct_test_umd1	—	**substructure**
ds.tst.s05.r01	ARE	author	author reference
ds.tst.s05.r02	ARE	specimen	specimen reference
ds.tst.s05.r03	ARE	device	device reference
ds.tst.s05.r04	ARE	location	location reference
ds.tst.s05.d01	ADE	datetime	date and time, seconds since epoch (UTC)
ds.tst.s05.d02	ADE	total_distance	total distance, measurement result
ds.tst.s05.d03	ADE	spacer_thickness	thickness of spacer disks, steel washer, measurement result
ds.tst.s05.d04	ADE	specimen_thickness	distance between actuator and sensor, calculated value
ds.tst.s05.a01	AAE	testname	test name
ds.tst.s05.a02	AAE	operator	operator name
ds.tst.s05.a03	AAE	procedure	procedure description
ds.tst.s05.a04	AAE	calculation	calculation description, formula

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Path	Type	Tag	Description
ds.tst.s05.a05	AAE	description	general description
ds.tst.s06	struct_test_utt	—	**substructure**
ds.tst.s06.r01	ARE	author	author reference
ds.tst.s06.r02	ARE	specimen	specimen reference
ds.tst.s06.r03	ARE	device	device reference
ds.tst.s06.r04	ARE	location	location reference
ds.tst.s06.d01	ADE	datetime	date and time, seconds since epoch (UTC)
ds.tst.s06.d02	ADE	zerotime	time span between adding water to cement and test start
ds.tst.s06.d03	ADE	interval_steps	number of interval steps, number of measurements
ds.tst.s06.d04	ADE	interval_length	interval length, time span between measurements
ds.tst.s06.d05	ADE	pulse_voltage	device setting, pulse generator voltage
ds.tst.s06.d06	ADE	pulse_width	device setting, pulse generator pulse width
ds.tst.s06.d07	ADE	sampling_rate	device setting, oscilloscope sampling rate
ds.tst.s06.d08	ADE	recorded_block_size	recording block size, number of recorded samples
ds.tst.s06.d09	ADE	num_init_samples	number of initial samples before trigger point
ds.tst.s06.d10	ADE	num_signals	number of recorded signals
ds.tst.s06.d11	ADE	sig_maturity	signal/specimen maturity array [num_signals x 1]
ds.tst.s06.d12	ADE	sig_times	signal sample time array [num_samples x 1]
ds.tst.s06.d13	ADE	sig_magnitudes	signal magnitude matrix [num_samples x num_signals]
ds.tst.s06.a01	AAE	testname	test name
ds.tst.s06.a02	AAE	operator	operator name
ds.tst.s06.a03	AAE	procedure	procedure description
ds.tst.s06.a04	AAE	calculation	calculation description, formula
ds.tst.s06.a05	AAE	description	general description
ds.tst.s06.a06	AAE	ss_filepath	settings file path, full qualified path
ds.tst.s06.a07	AAE	ss_filename	settings file name
ds.tst.s06.a08	AAE	ss_filehash	settings file hash, sha-256
ds.tst.s06.a09	AAE	mm_filepath	measurements file path, full qualified path
ds.tst.s06.a10	AAE	mm_filename	measurements file name
ds.tst.s06.a11	AAE	mm_filehash	measurements file hash, sha-256

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Path	Type	Tag	Description
ds.tst.s06.a12	AAE	data_dirpath	signal data directory path, full qualified path
ds.tst.s06.a13	AAE	data_filepath	signal data file path list, full qualified paths num_signals x 1
ds.tst.s06.a14	AAE	data_filename	signal data file name list num_signals x 1
ds.tst.s06.a15	AAE	data_filehash	signal data file hash list, sha-256 num_signals x 1
ds.tst.s07	struct_test_utt	—	**substructure**
ds.tst.s07.r01	ARE	author	author reference
ds.tst.s07.r02	ARE	specimen	specimen reference
ds.tst.s07.r03	ARE	device	device reference
ds.tst.s07.r04	ARE	location	location reference
ds.tst.s07.d01	ADE	datetime	date and time, seconds since epoch (UTC)
ds.tst.s07.d02	ADE	zerotime	time span between adding water to cement and test start
ds.tst.s07.d03	ADE	interval_steps	number of interval steps, number of measurements
ds.tst.s07.d04	ADE	interval_length	interval length, time span between measurements
ds.tst.s07.d05	ADE	pulse_voltage	device setting, pulse generator voltage
ds.tst.s07.d06	ADE	pulse_width	device setting, pulse generator pulse width
ds.tst.s07.d07	ADE	sampling_rate	device setting, oscilloscope sampling rate
ds.tst.s07.d08	ADE	recorded_block_size	recording block size, number of recorded samples
ds.tst.s07.d09	ADE	num_init_samples	number of initial samples before trigger point
ds.tst.s07.d10	ADE	num_signals	number of recorded signals
ds.tst.s07.d11	ADE	sig_maturity	signal/specimen maturity array [num_signals x 1]
ds.tst.s07.d12	ADE	sig_times	signal sample time array [num_samples x 1]
ds.tst.s07.d13	ADE	sig_magnitudes	signal magnitude matrix [num_samples x num_signals]
ds.tst.s07.a01	AAE	testname	test name
ds.tst.s07.a02	AAE	operator	operator name
ds.tst.s07.a03	AAE	procedure	procedure description
ds.tst.s07.a04	AAE	calculation	calculation description, formula
ds.tst.s07.a05	AAE	description	general description
ds.tst.s07.a06	AAE	ss_filepath	settings file path, full qualified path
ds.tst.s07.a07	AAE	ss_filename	settings file name
ds.tst.s07.a08	AAE	ss_filehash	settings file hash, sha-256

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Path	Type	Tag	Description
ds.tst.s07.a09	AAE	mm_filepath	measurements file path, full qualified path
ds.tst.s07.a10	AAE	mm_filename	measurements file name
ds.tst.s07.a11	AAE	mm_filehash	measurements file hash, sha-256
ds.tst.s07.a12	AAE	data_dirpath	signal data directory path, full qualified path
ds.tst.s07.a13	AAE	data_filepath	signal data file path list, full qualified paths num_signals x 1
ds.tst.s07.a14	AAE	data_filename	signal data file name list num_signals x 1
ds.tst.s07.a15	AAE	data_filehash	signal data file hash list, sha-256 num_signals x 1
ds.tst.s08	struct_test_tem	—	**substructure**
ds.tst.s08.r01	ARE	author	author reference
ds.tst.s08.r02	ARE	specimen	specimen reference
ds.tst.s08.r03	ARE	device	device reference
ds.tst.s08.r04	ARE	location	location reference
ds.tst.s08.d01	ADE	datetime	date and time, seconds since epoch (UTC)
ds.tst.s08.d02	ADE	tem_maturity	temperature measurement time array, specimen maturity [num_signals x 1]
ds.tst.s08.d03	ADE	tem_tcpl1	thermocouple-1, temperature magnitude array [num_signals x 1]
ds.tst.s08.d04	ADE	tem_tcpl2	thermocouple-2, temperature magnitude array [num_signals x 1]
ds.tst.s08.d05	ADE	tem_tcpl3	thermocouple-3, temperature magnitude array [num_signals x 1]
ds.tst.s08.d06	ADE	tem_tcpl4	thermocouple-4, temperature magnitude array [num_signals x 1]
ds.tst.s08.a01	AAE	testname	test name
ds.tst.s08.a02	AAE	operator	operator name
ds.tst.s08.a03	AAE	procedure	procedure description
ds.tst.s08.a04	AAE	calculation	calculation description, formula
ds.tst.s08.a05	AAE	description	general description
ds.tst.s08.a06	AAE	placement_tcpl1	placement of thermocouple 1
ds.tst.s08.a07	AAE	placement_tcpl2	placement of thermocouple 2
ds.tst.s08.a08	AAE	placement_tcpl3	placement of thermocouple 3
ds.tst.s08.a09	AAE	placement_tcpl4	placement of thermocouple 4
ds.tst.s08.a10	AAE	data_dirpath	temperature data directory path, full qualified path
ds.tst.s08.a11	AAE	data_filepath	temperature data file path
ds.tst.s08.a12	AAE	data_filename	temperature data file name

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Path	Type	Tag	Description
ds.tst.s08.a13	AAE	data_filehash	temperature data file hash, sha-256
ds.tst.s09	struct_test_env1	—	**substructure**
ds.tst.s09.r01	ARE	author	author reference
ds.tst.s09.r02	ARE	device	device reference
ds.tst.s09.r03	ARE	location	location reference
ds.tst.s09.d01	ADE	datetime	date and time, seconds since epoch (UTC)
ds.tst.s09.d02	ADE	temperature	environment temperature at test start
ds.tst.s09.a01	AAE	testname	test name
ds.tst.s09.a02	AAE	operator	operator name
ds.tst.s09.a03	AAE	procedure	procedure description
ds.tst.s09.a04	AAE	calculation	calculation description, formula
ds.tst.s09.a05	AAE	description	general description

Table 8: Raw data archive listing (content of **ts4_rawdata.tar.xz**).

File name	SHA256 checksum
ts4_wc040_d25_w100.zip	a5a824f1b96ed6ae568778ee56e01209f2f5724481cfe6eba9236e90b2cf25c8
ts4_wc040_d50_w025.zip	49fa392db12cc632039b41229ffe1773a555bb36b280603e44d5f4ce99577023
ts4_wc040_d50_w075_a.zip	e9c5c0591d52627ee0c43527b8dfc001e38f81ff647268acdec547507e1e356e
ts4_wc040_d50_w075.zip	f901285b8da33dbe491146c1ddc716cde35b4fcb6d0533c1773854c2d4bbb4cc
ts4_wc040_d50_w100.zip	d19956305c556fb110a27e675b7896044f69c6ed09d378e3d89689358d1c088f
ts4_wc040_d50_w125.zip	34faddb2052fd23343e6a0b01c759c89bc14cbd5a7cc7d7f6ea50731aebbd1cf
ts4_wc045_d25_w100.zip	db8b705dc68b1b2618964c7b40198bf87b036ef8ce1152593a6aa77ab0310076
ts4_wc045_d50_w025.zip	76bdab225b4fcf8d1850a364f12cd788e165fdfacf6d421e5de532fe6b6eeb5f
ts4_wc045_d50_w075_a.zip	fce4447d6dd6bb54e145bf33c2fc900e30e0caf56ff4c228d7cbcae9d5cce380
ts4_wc045_d50_w075.zip	7f64eae5ab1a6ec3def0df9db5d568dad81c27a71d36fdee2556636493e8df99
ts4_wc045_d50_w100.zip	0f02e9f841154a0c9525cf1065a7f471eb7289982996ad978da3109831e7fde9
ts4_wc045_d50_w125.zip	8b80d22b19ec1bd45671d12d962cb9848ca1e6ed5854f8c5873b45e1b6908a08
ts4_wc050_d25_w100.zip	ada13021e164257b3f0e6f5cd593a4811ae1ff26c9d5cec0939de0fbb11222c8
ts4_wc050_d50_w025.zip	b2b0d5d9a370f469a04df06b85eb9264aff1088e939b79aae9d3c703342baca4
ts4_wc050_d50_w075.zip	f7e38d8aa31c2869164633583cd88d8c8133fdb1a127e8b23d6e5ddc696793cc
ts4_wc050_d50_w100.zip	c3b181f85ea0860434b73a74940215142f58c316ba8837b5212e50b3d34b7d69
ts4_wc050_d50_w125_a.zip	54e8cad485aadf6d71ea4bf7069f91126f51ef13fafc194d758472369ec33a75
ts4_wc050_d50_w125.zip	3e2ff6930da50683e9c9d530ef7a9a9537c4a53467b1aa6fcd223e3f7afd6b5a
ts4_wc055_d25_w100.zip	82520688e4ca0459c4b4cdd78c263de123683779b4bfd74772c413313560f3c1
ts4_wc055_d50_w025.zip	b4fee2583a72be00330cfdde27304cbbcd563c96c59423144c6490e74cb04e39
ts4_wc055_d50_w075.zip	50878d2ee184e35d52c4dc940c8465c6339f09ce23e7962391b8af0945ba1389
ts4_wc055_d50_w100.zip	b472a181991a2a9bef2bcde79feb92cc77b973b0a4d42eb50f5201c69c2c81ef
ts4_wc055_d50_w125.zip	ad3ffe81101987ab13df6c99be87b124563057e8900a5901666b5acb53b10b8c
ts4_wc060_d25_w100.zip	46f8fec79851d09e7ffccc3f0a51bad4f35848eb4eee87d570f5a49b2d5ebdd5
ts4_wc060_d50_w025.zip	115f47486aed97e6b8e2977e13e6b54d28df00896462ec69f31b109c3b01265a
ts4_wc060_d50_w075.zip	4d026b6f62b0c64cdd765eb8f333ea0c24309686c1f0e5273389484c4390c33d
ts4_wc060_d50_w100.zip	9c30ba1004c39b56aef8f9b0d09fee45ebb7385dfaeeb79f1f9af01b806d69ec
ts4_wc060_d50_w125_a.zip	fa653523f54e60d95275ec99841820979034a443e7b50c251331a6cff98c1ba7
ts4_wc060_d50_w125.zip	79ccc82b011ad0c9dffd4275562f4cb7a7238f5664bb50df81e7d019c8f1eb69

Table 9: Data set file listing (content of **ts4_datasets.tar.xz**).

File name	SHA256 checksum
ts4_wc040_d25_w100.oct	33d72b29a8389c7320ae422e544a908aa23da82a6b499457742c5c67aa13fcb8
ts4_wc040_d50_w025.oct	cd0793625922a4f9cdcc93256ae7edad2cb40e61dc460c05e193ae09516a2f4d
ts4_wc040_d50_w075_a.oct	711af5d054a0c05f0d73df2b441db144d21116039661d056f8ba374da9f11e12
ts4_wc040_d50_w075.oct	1241a77b8857b0b7eacac760be42d4718cda6552124e639e65b8d8291e2dfeb9
ts4_wc040_d50_w100.oct	35feb9fad98dbd1536e52336573637d7b645adbf4aaab862da1c14079cb8d718
ts4_wc040_d50_w125.oct	684a20e84041e14234a10c491a8ba1b5218700244dad950457e80b9346ee37a3
ts4_wc045_d25_w100.oct	8e45b12219d0618509cbbd26bb8ca1abc76eadd0f0515ce7426372dfff0cdda3
ts4_wc045_d50_w025.oct	4e6cdf278a5382b7f0ad67bd6fd0ffc48c6f7d3d202c39277f7c8f70dbb9d803
ts4_wc045_d50_w075_a.oct	ecc945e95b1ef3addd96ce2a4df9aa50757595f357ba18b00df606975d0a5c6c
ts4_wc045_d50_w075.oct	052e2cb6e1b2935762f86fe4fa2d069ae483b97065f99f95ee11404dbdb51117
ts4_wc045_d50_w100.oct	40cae854cec37ade2b24722b2bd0af9304c2b77356205e22cf704aa81a8d4e3d
ts4_wc045_d50_w125.oct	e0c6dd8f7b302d46a09b1abbceafc5cd043999e9139e3da6a4b9c11e668f9cdd
ts4_wc050_d25_w100.oct	7bea3d3f55cdd6213b73f8a5fe059e170cb18456142ef8bdb903a00a06e0dce7

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File name	SHA256 checksum
ts4_wc050_d50_w025.oct	6b88a7da1f327868fc4c5528d909068a1636e9bc625b70e0d323ecba528c64af
ts4_wc050_d50_w075.oct	0555e11b436db43c087145d37805df852e602f83400bdfd77f653abd59042ad0
ts4_wc050_d50_w100.oct	47a6afe600a87092a39a89d353a897a98e2c812379e2982d4ee1c5892714be46
ts4_wc050_d50_w125_a.oct	d7feeacf6c4e7417e28f58f485b0cdf281e400f200bc9ca905f4460ea674b03d
ts4_wc050_d50_w125.oct	9467eb7985811d6f9334f61cac54c628f1b1b76cd2951e89843245be1b07b0a7
ts4_wc055_d25_w100.oct	ebeba9e053d4369bf9ce10d93603324730469fe35d1f7b9eef8b6e387b7a25e7
ts4_wc055_d50_w025.oct	5cf96de8116a8746d5a7b7b5a1341a989680590a942e0747ded49bef11776195
ts4_wc055_d50_w075.oct	3ecbcdd2b8b87a4ac9de5fedbf5b1df839ac51e029e04c2dd76d9eb77acf4527
ts4_wc055_d50_w100.oct	e5d2a02cf175e7ee1a066b140568f5b2865c01bd57519e9c98946e7aec5c635e
ts4_wc055_d50_w125.oct	4d50fe746f6c41a6b1adca46eeda8e57cdc1075017be1c8311d359e44a0b9072
ts4_wc060_d25_w100.oct	24b01dcf8ef26c3c850b37a7fb4659a7b4b35a5ba4db65bfd807ab73160baec6
ts4_wc060_d50_w025.oct	35a0c947d606101a524004b92f03ed0cbdf529670e88ad002d9c3f1c53a52aeb
ts4_wc060_d50_w075.oct	88219461f87941e65ef7f59b3992ab86713f298378ca312441b31e9329feccf6
ts4_wc060_d50_w100.oct	4dde718766390ef162d182c586aaf013999f0b707cfc80a6b9a9b0a2946175b9
ts4_wc060_d50_w125_a.oct	7c1202e97010754f069ed309f78f1e18b7af5faaa6edc95c89b3006780783ec4
ts4_wc060_d50_w125.oct	2de8c5694068f6c9690a2dd69f1011bebd3debf3d6f3bc83f4cb11e72b77715a