Accuracy of Concrete Creep Predictions Based on Extrapolation of Short-Time Data

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Contents

Motivation

- Set up optimal time for short-time data

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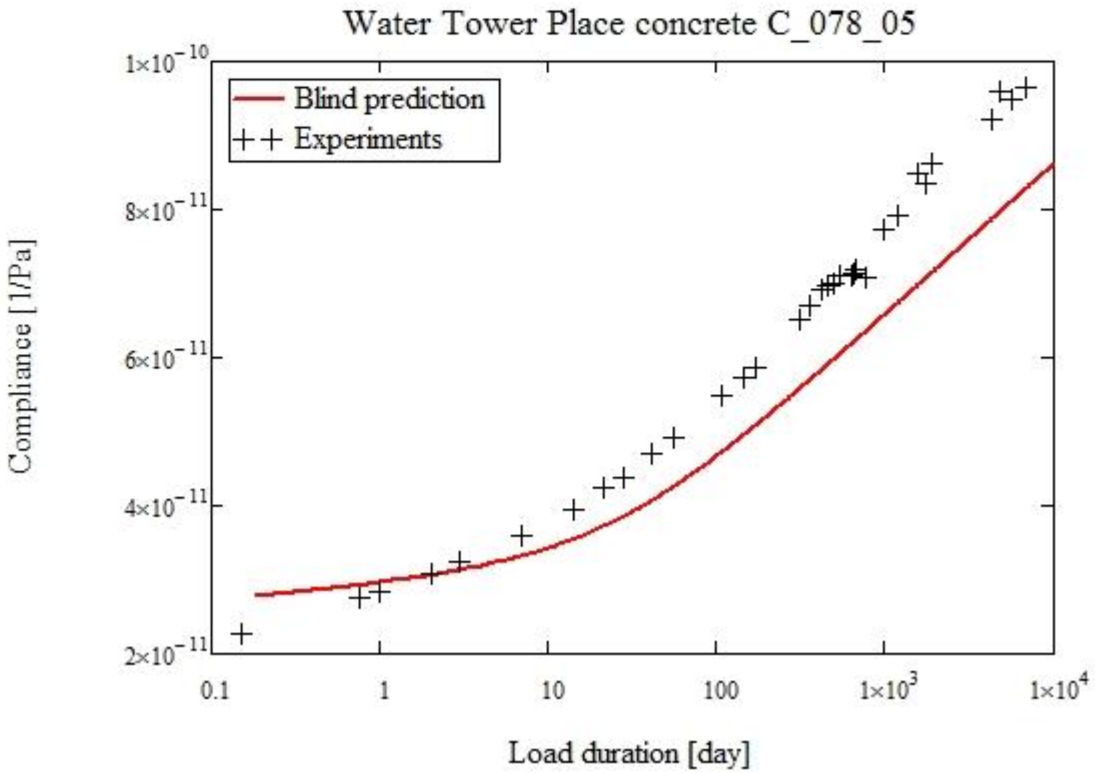

Motivation

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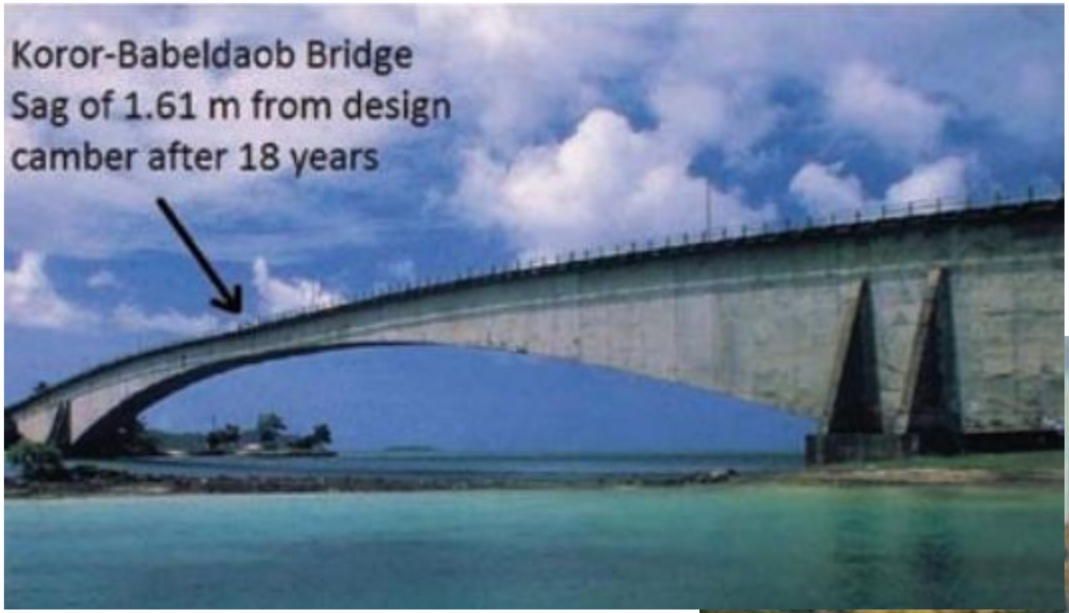

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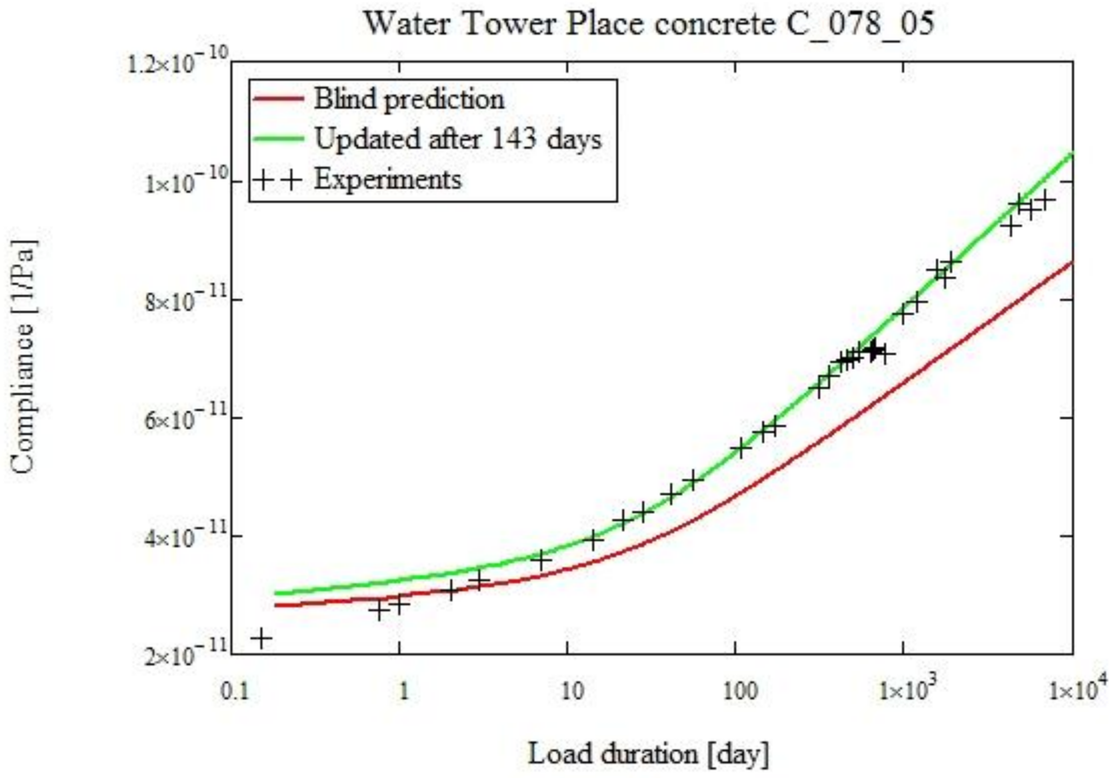


Motivation

- Set up optimal time for short-time data

New tasks:

- Improving of updating method
- Comparison of accuracy of updated predictions

Creep Models

Model B3

$$J(t,t') = q_1 + q_2 Q(t,t') + q_3 \ln[1 + (t - t')^{0.1}] + q_4 \ln\left(\frac{t}{t'}\right) + J_d(t,t')$$

Fib Model 2010

ACI 209 Model

GL Model

Creep Models

Model B3

***Fib* Model 2010**

$$J(t,t') = \frac{1}{E_c} e^{-\frac{s}{2}\left(1-\sqrt{\frac{28}{t'}}\right)} + \frac{\varphi_{RH}\beta_f}{E_c} \frac{1}{0.1 + t'^{0.2}} \left(\frac{t - t'}{\beta_H \beta_T + t - t'}\right)^{0.3}$$

ACI 209 Model

GL Model

Creep Models

Model B3

Fib Model 2010

ACI 209 Model

$$J(t,t') = \frac{1}{E_c}\sqrt{b+\frac{a}{t'}}\left[1+\frac{2.35\gamma}{(t')^m}\frac{(t-t')^{0.6}}{10+(t-t')^{0.6}}\right]$$

GL Model

Creep Models

Model B3

Fib Model 2010

ACI 209 Model

GL Model

$$J(t,t') = \frac{1}{3.5 + (E_c - 3.5)e^{\frac{s}{2}\left(1-\sqrt{\frac{28}{t'}}\right)}} + \frac{\varphi}{E_c}\left[\frac{2(t-t')^{0.3}}{(t-t')^{0.3}+14} + \sqrt{\frac{7(t-t')}{t'(t-t'+7)}} + c_h\sqrt{\frac{t-t'}{t-t'+0.12(V/S)^2}}\right]$$

Test Data

Comprehensive database on concrete creep and shrinkage *(Zdeněk P. Bažant & Guang-Hua Li)*

<u>Criteria for selection</u>

Stress level $\sigma_c \leq 0.45 f_{c\_28}$

Humidity $H \geq 99\%$

Temperature $(5°C \leq T \leq 50°C)$

Compressive strength $f_{c\_28} \leq 82MPa$

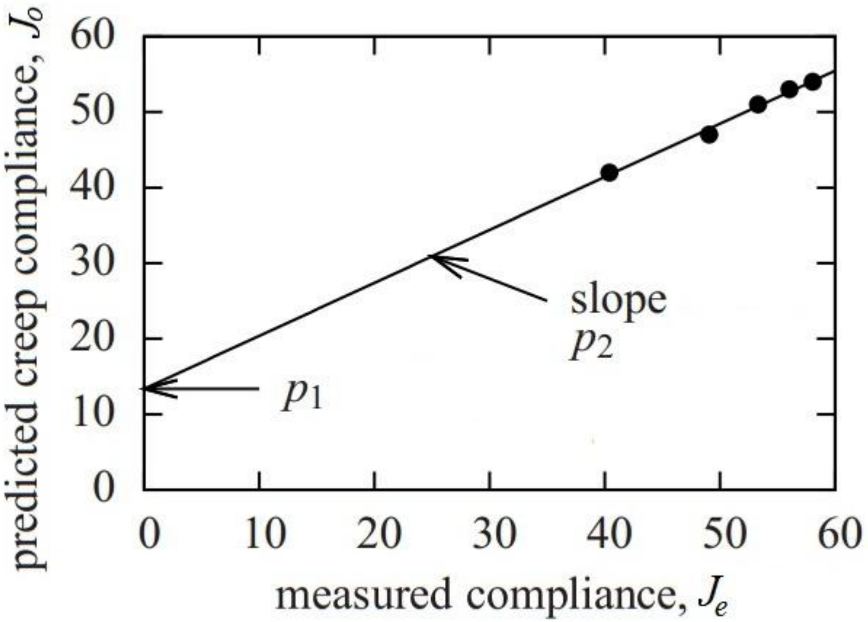
Time of loading $t \geq 1000 days$

1	ID	Author	Region	Year	File	TestNo	Ref Number	wc	ac	c	cCEB	SiO2	FlyAsh	WR	Re	AEA	fc28	E28	Geometry
2	1	Dutron [1]	B	1936	c_001_01	1	38	0,56	6,46	289	R	0	0	0	0	0	28,4		P 100x400
3	2	Dutron [1]	B	1936	c_001_02	2	38	0,56	6,46	289	R	0	0	0	0	0	28,4		P 100x400
4	3	Komm	B	1936	c_001_03	3	38	0,56	6,46	289	R	0	0	0	0	0	28,4		P 100x400
5	4	Dutron [1]	B	1936	c_001_04	4	38	0,56	6,46	289	R	0	0	0	0	0	28,4		P 100x400
6	5	Dutron [1]	B	1936	c_001_05	5	38	0,56	6,46	289	R	0	0	0	0	0	28,4		P 100x400
7	6	Dutron [1]	B	1936	c_001_06	6	38	0,56	6,46	289	R	0	0	0	0	0	28,4		P 100x400
8	7	Hanson [2]	USA	1953	c_002_01	1	50	0,58	5,624	346	SL	0	0	0	0	0	22,3		C 152x660
9	8	Hanson [2]	USA	1953	c_002_02	2	50	0,56	6,14	320	SL	0	0	0	0	0	34,3		C 152x406
10	9	Hanson [2]	USA	1953	c_002_03	3	50	0,56	6,14	320	SL	0	0	0	0	0	34,3		C 152x406
11	10	Hanson [2]	USA	1953	c_002_04	4	50	0,56	6,14	320	SL	0	0	0	0	0	34,3		C 152x406
12	11	Hanson [2]	USA	1953	c_002_05	5	50	0,56	6,14	320	SL	0	0	0	0	0	34,3		C 152x406
13	12	Hanson [2]	USA	1953	c_002_06	6	50	0,56	6,14	320	SL	0	0	0	0	0	34,3		C 152x406
14	13	Troxel [5]	USA	1958	c_005_01	1	50	0,59	5,669	320	R	0	0	0	0	0	16,5		C 102x356
15	14	Troxel [5]	USA	1958	c_005_02	2	101	0,59	5,669	320	R	0	0	0	0	0	16,5		C 102x356
16	15	Troxel [5]	USA	1958	c_005_03	3	101	0,59	5,669	320	R	0	0	0	0	0	16,5		C 102x356
17	16	Troxel [5]	USA	1958	c_005_04	4	101	0,59	5,669	320	R	0	0	0	0	0	16,5		C 102x356
18	17	Weil [6] A	D	1959	c_006_01	1	103	0,52	5,385	338	SL	0	0	0	0	0	25,4		C 100x400
19	18	Weil [6] A	D	1959	c_006_02	2	103	0,52	5,385	338	SL	0	0	0	0	0	25,4		C 200x800
20	19	Weil [6] A	D	1959	c_006_03	3	103	0,52	5,385	338	SL	0	0	0	0	0	25,4		C 300x1200
21	20	Weil [6] A	D	1959	c_006_04	4	103	0,52	5,385	338	SL	0	0	0	0	0	25,4		C 600x1800
22	21	Weil [6] B	D	1959	c_006_05	5	103	0,54	5,4	337	SL	0	0	0	0	0	28		C 100x400
23	22	Weil [6] B	D	1959	c_006_06	6	103	0,54	5,4	337	SL	0	0	0	0	0	28		C 100x400
24	23	Weil [6] C	D	1959	c_006_07	7	103	0,52	5,031	358	R	0	0	0	0	0	46,9		C 100x400
25	24	Weil [6] C	D	1959	c_006_08	8	103	0,52	5,031	358	R	0	0	0	0	0	46,9		C 100x400
26	25	Weil [6] B	D	1959	c_006_09	9	103	0,54	5,4	337	SL	0	0	0	0	0	28		C 100x400
27	26	Weil [6] B	D	1959	c_006_10	10	103	0,54	5,4	337	SL	0	0	0	0	0	28		C 100x400
28	27	Weil [6] C	D	1959	c_006_11	11	103	0,52	5,031	358	R	0	0	0	0	0	46,9		C 100x400
29	28	Weil [6] C	D	1959	c_006_12	12	103	0,52	5,031	358	R	0	0	0	0	0	46,9		C 100x400
30	29	Hummel [11]	D	1962	c_011_01	1	6	0,55	5,396	334	SL	0	0	0	0	0	26,9		C 200x800
31	30	Hummel [11]	D	1962	c_011_02	2	6	0,55	5,396	334	SL	0	0	0	0	0	26,9		C 200x800
32	31	Hummel [11]	D	1962	c_011_03	3	6	0,55	5,396	334	SL	0	0	0	0	0	26,9		C 200x800
33	32	Hummel [11]	D	1962	c_011_04	4	6	0,55	5,396	334	R	0	0	0	0	0	41,9		C 200x800
34	33	Hummel [11]	D	1962	c_011_05	5	6	0,55	5,396	334	R	0	0	0	0	0	41,9		C 200x800
35	34	Hummel [11]	D	1962	c_011_06	6	6	0,55	5,396	334	R	0	0	0	0	0	41,9		C 200x800
36	35	Hummel [11]	D	1962	c_011_07	7	6	0,38	5,391	350	SL	0	0	0	0	0	43,1		C 200x800
37	36	Hummel [11]	D	1962	c_011_08	8	6	0,45	5,392	345	SL	0	0	0	0	0	35,3		C 200x800
38	37	Hummel [11]	D	1962	c_011_09	9	6	0,65	5,393	328	SL	0	0	0	0	0	19		C 200x800

(40 tests from 12 laboratories)

Standard Updating

Linear Regression



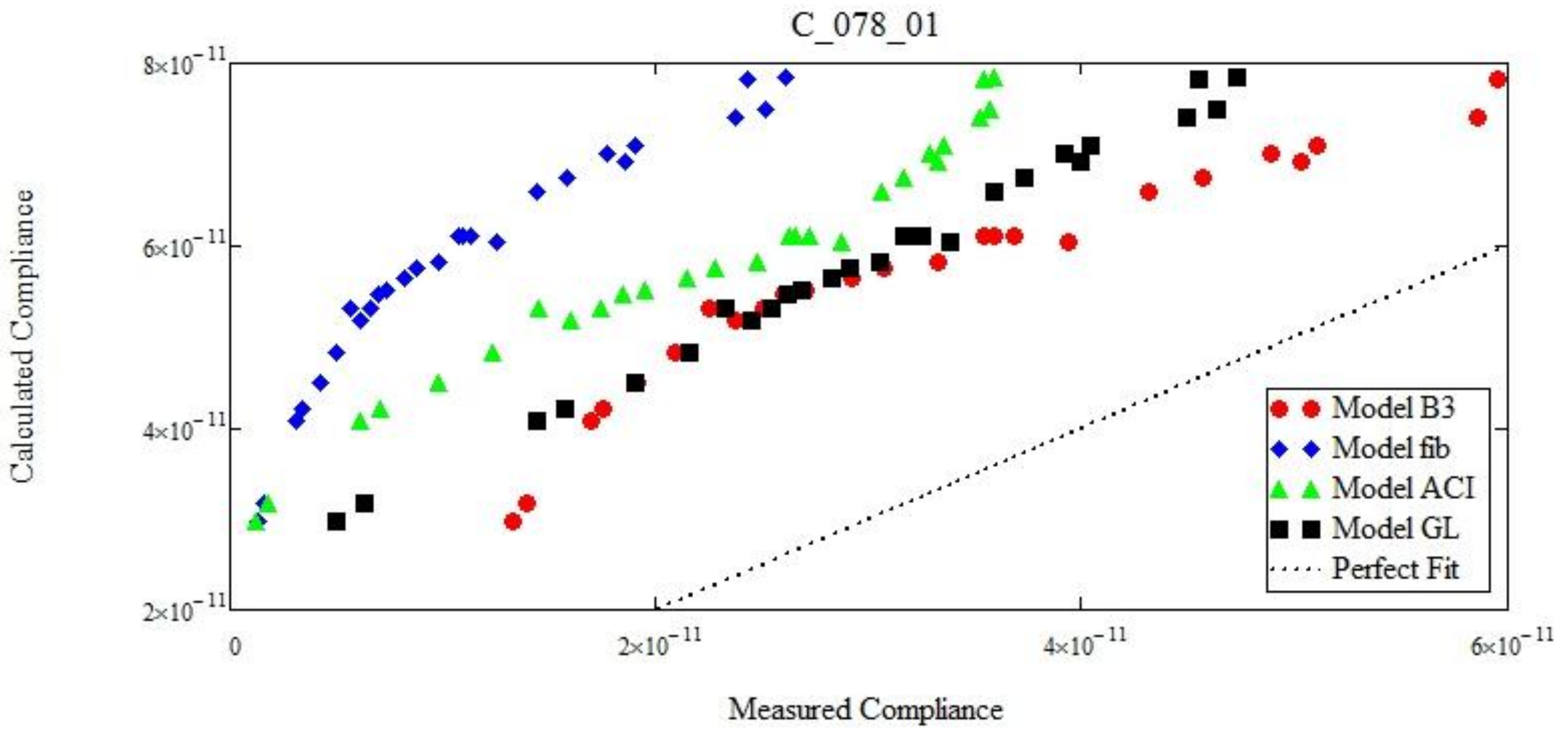
$$J_u(t,t') = p_1 + p_2 J_o(t,t')$$

$$f(p_1,p_2) = \sum_{i=1}^{m} [p_1 + p_2 J_o(t_i,t') - J_e(t_i)]^2$$

Standard Updating

Imperfections

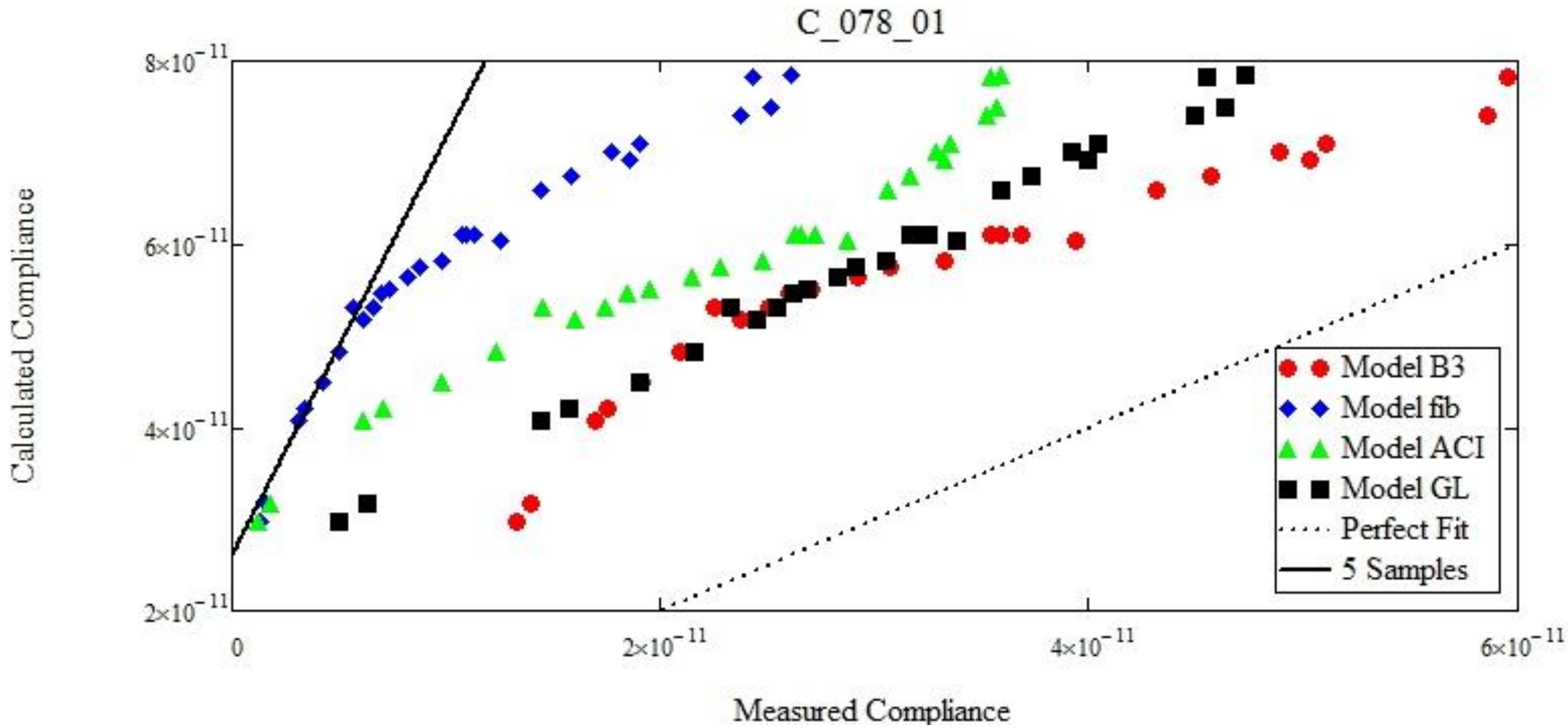
Influence of early measurements



Standard Updating

Imperfections

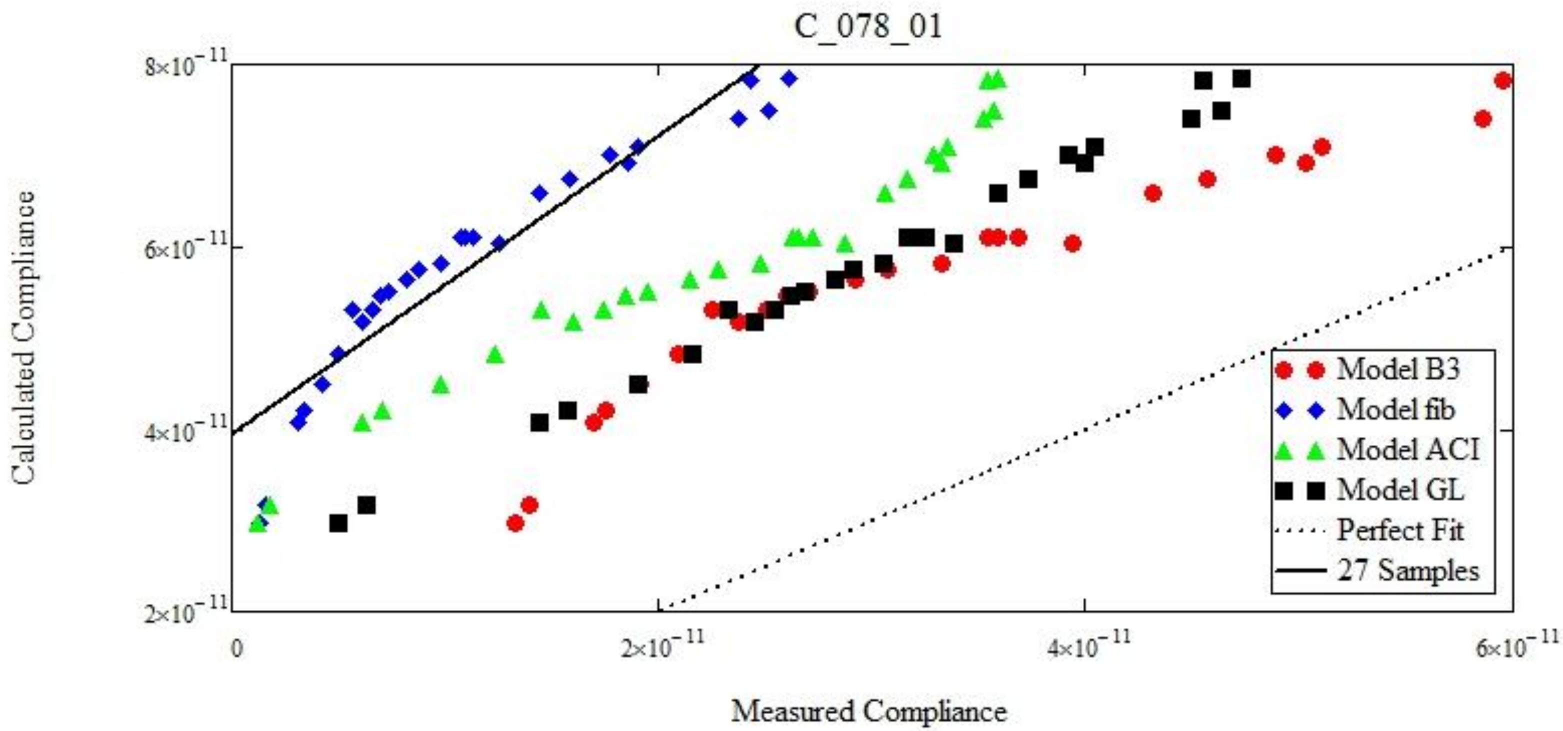
Influence of early measurements



Standard Updating

Imperfections

Influence of early measurements



Modified Updating

Weight factors

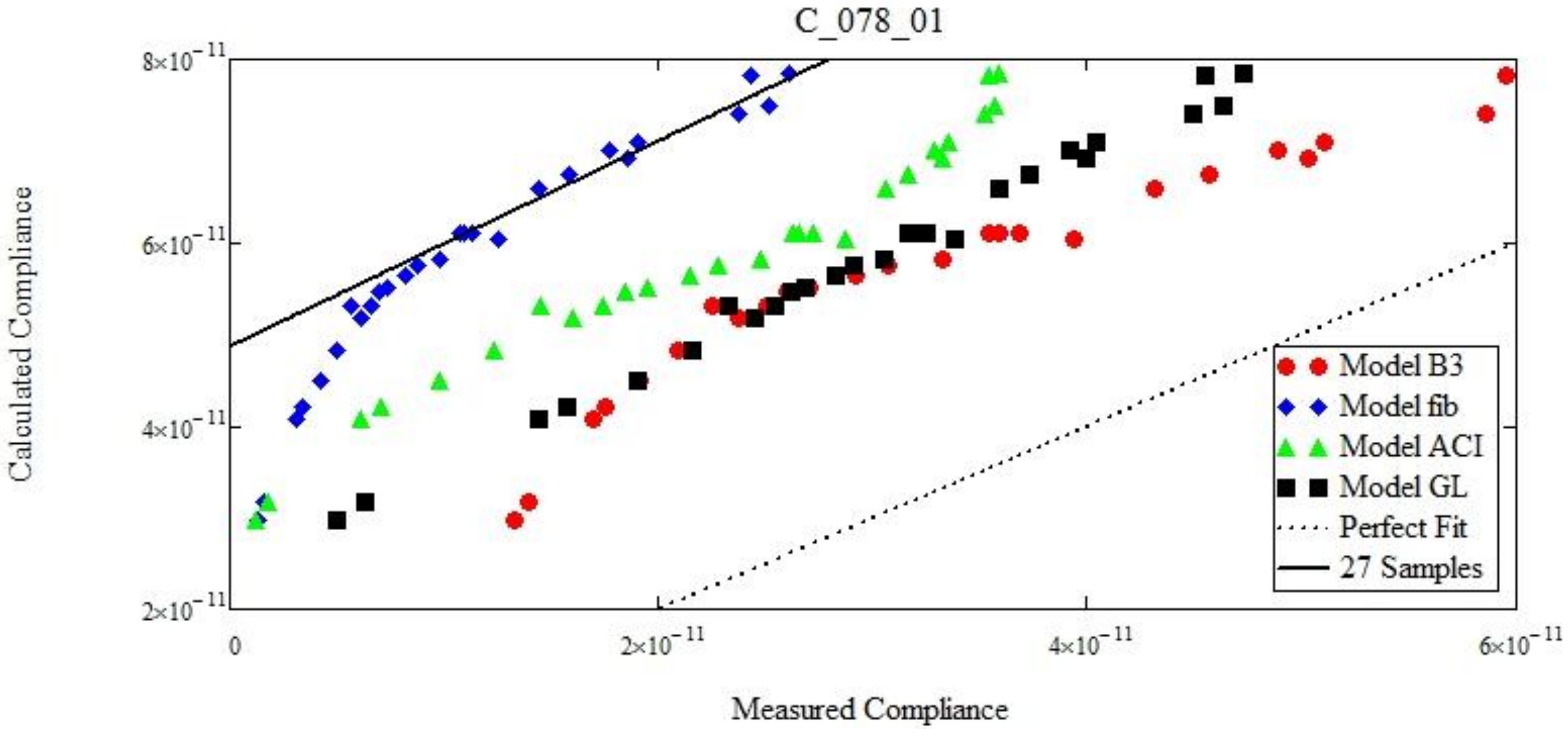
$$f(p_1, p_2) = \sum_{i=1}^{m} (t_i - t')[p_1 + p_2 J_o(t_i, t') - J_e(t_i)]^2$$

$$p_2 = \frac{w \sum_{i=1}^{m} (J_i^o J_i^e w_i) - \sum_{i=1}^{m} (J_i^o w_i) \sum_{i=1}^{m} (J_i^e w_i)}{w \sum_{i=1}^{m} (J_i^o w_i)^2 - \left(\sum_{i=1}^{m} (J_i^o w_i)\right)^2}$$

$$p_1 = \frac{\sum_{i=1}^{m} (J_i^e w_i)}{w} + p_2 \frac{\sum_{i=1}^{m} (J_i^o w_i)}{w}$$

Modified Updating

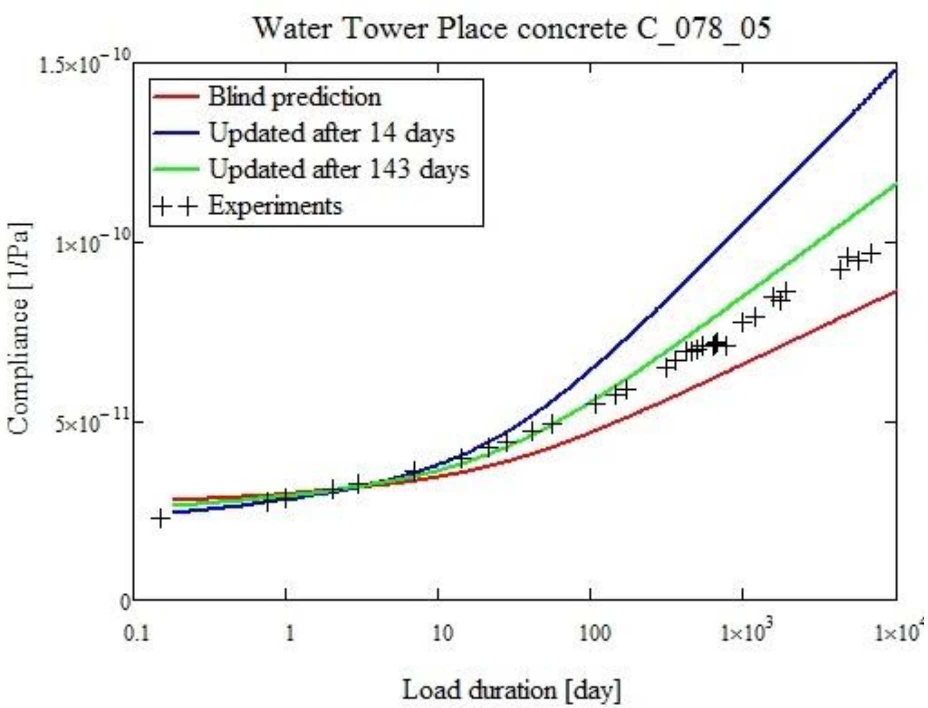
Elimination of influence of early measurements



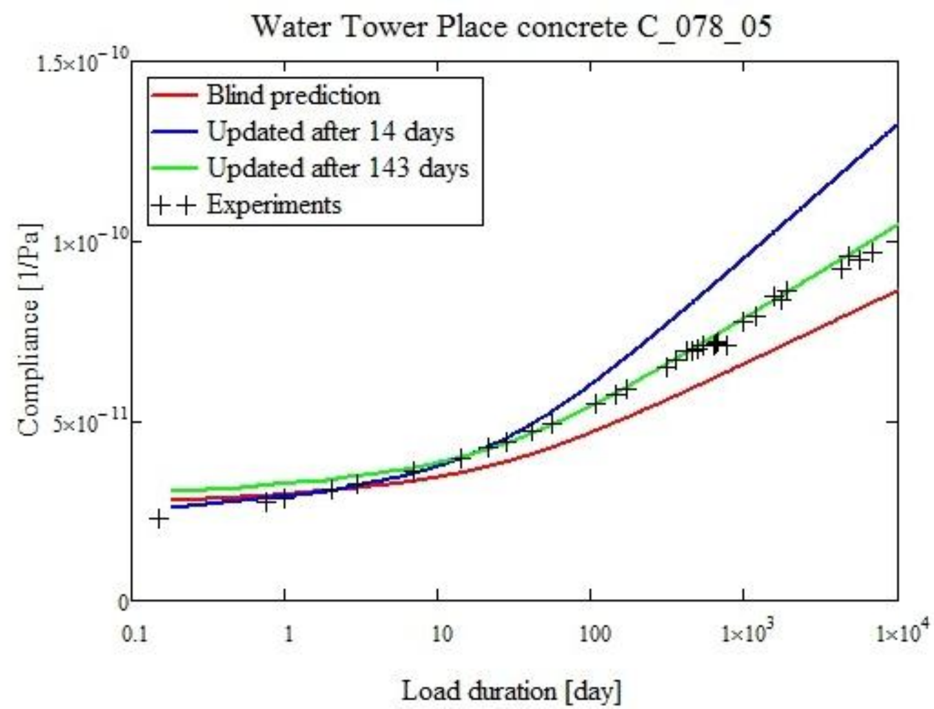
Modified Updating

Improving of updating method

Standard Updating



Modified Updating



Accuracy of Updated Predictions

Absolute residual error [1/Pa]

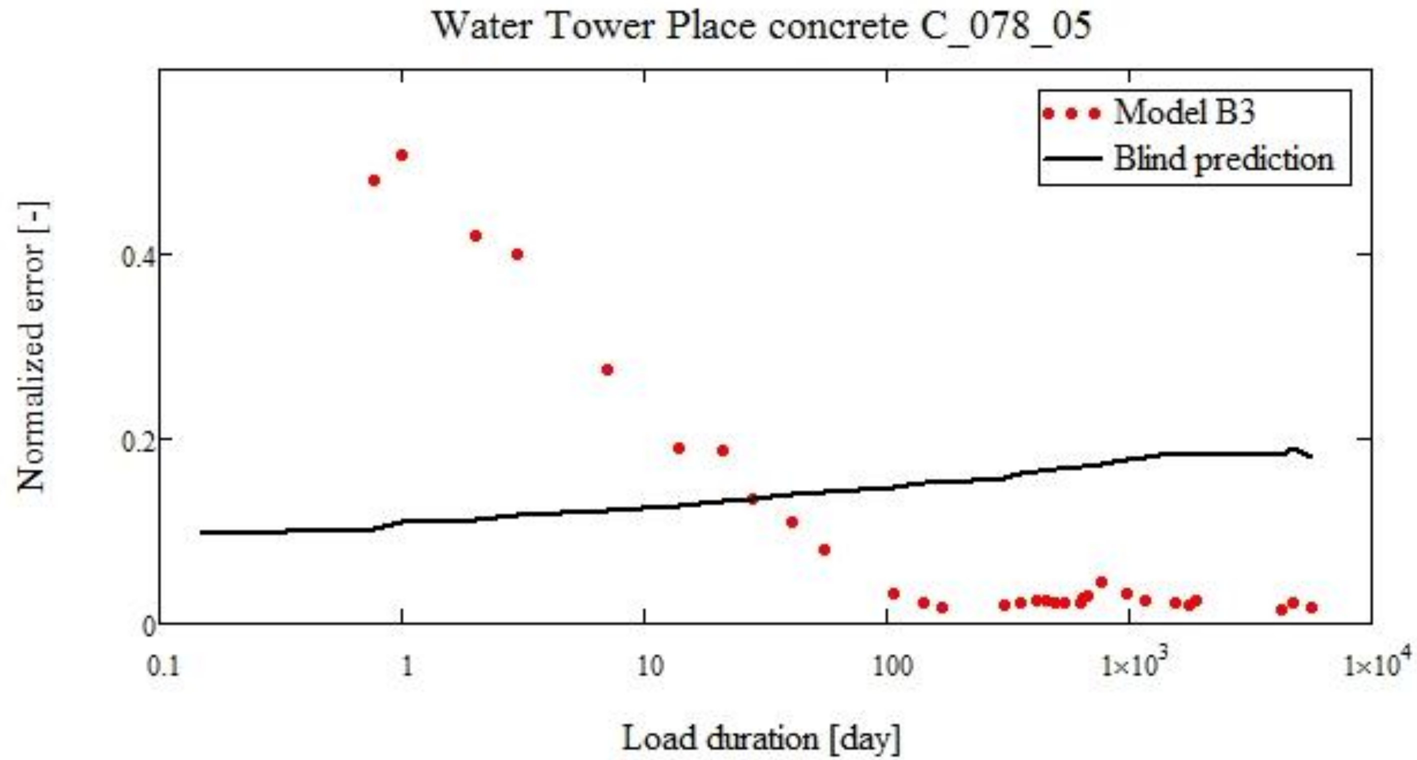
$$e_u^{(m)} = \sqrt{\frac{\sum_{i=m+1}^{n} \ln \frac{t_{i+1} - t'}{t_{i-1} - t'} [J_u(t_i, t') - J_e(t_i)]^2}{\sum_{i=m+1}^{n} \ln \frac{t_{i+1} - t'}{t_{i-1} - t'}}}$$

Normalized residual error [-]

$$e_n^{(m)} = \frac{e_u^{(m)}}{J(1000 + t', t')}$$

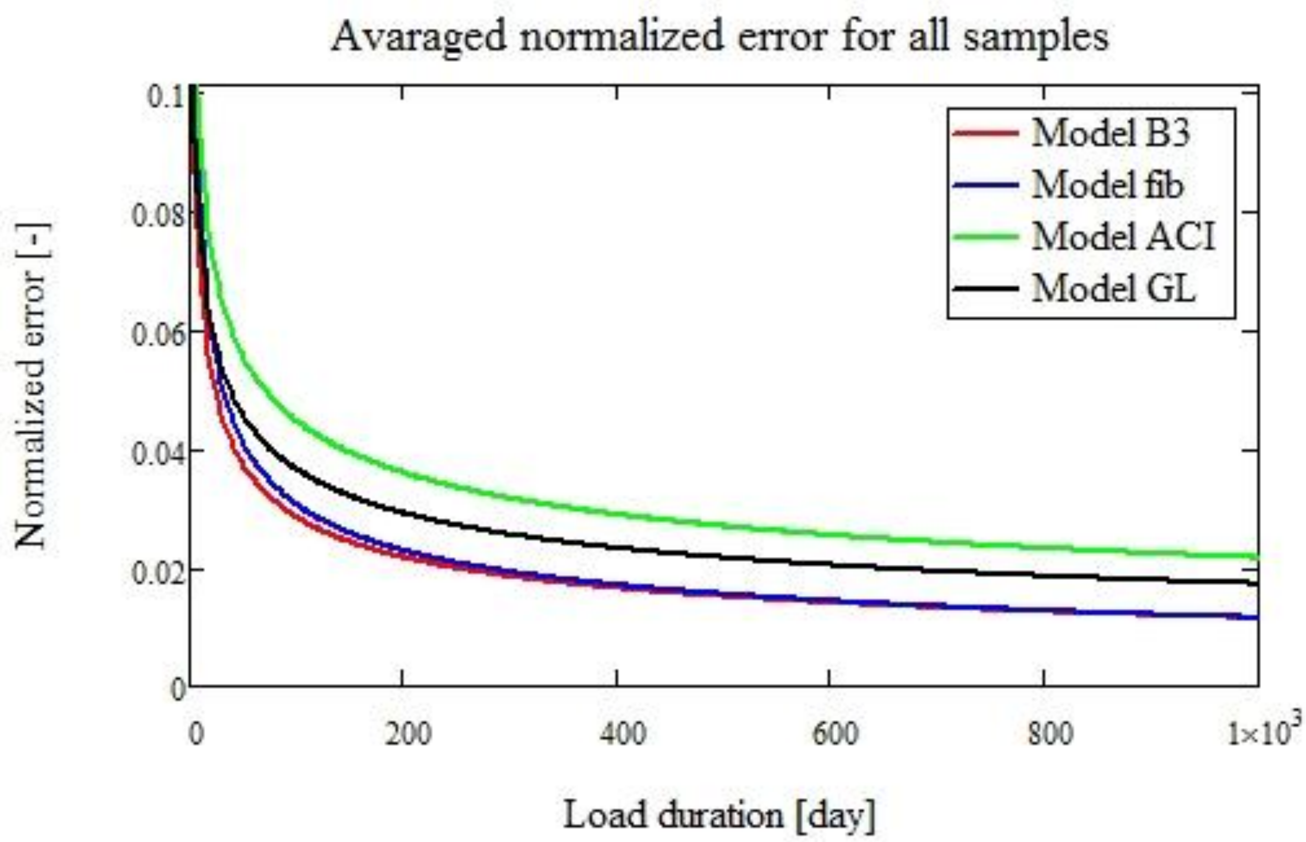
Accuracy of Updated Predictions

Normalized residual error [-]

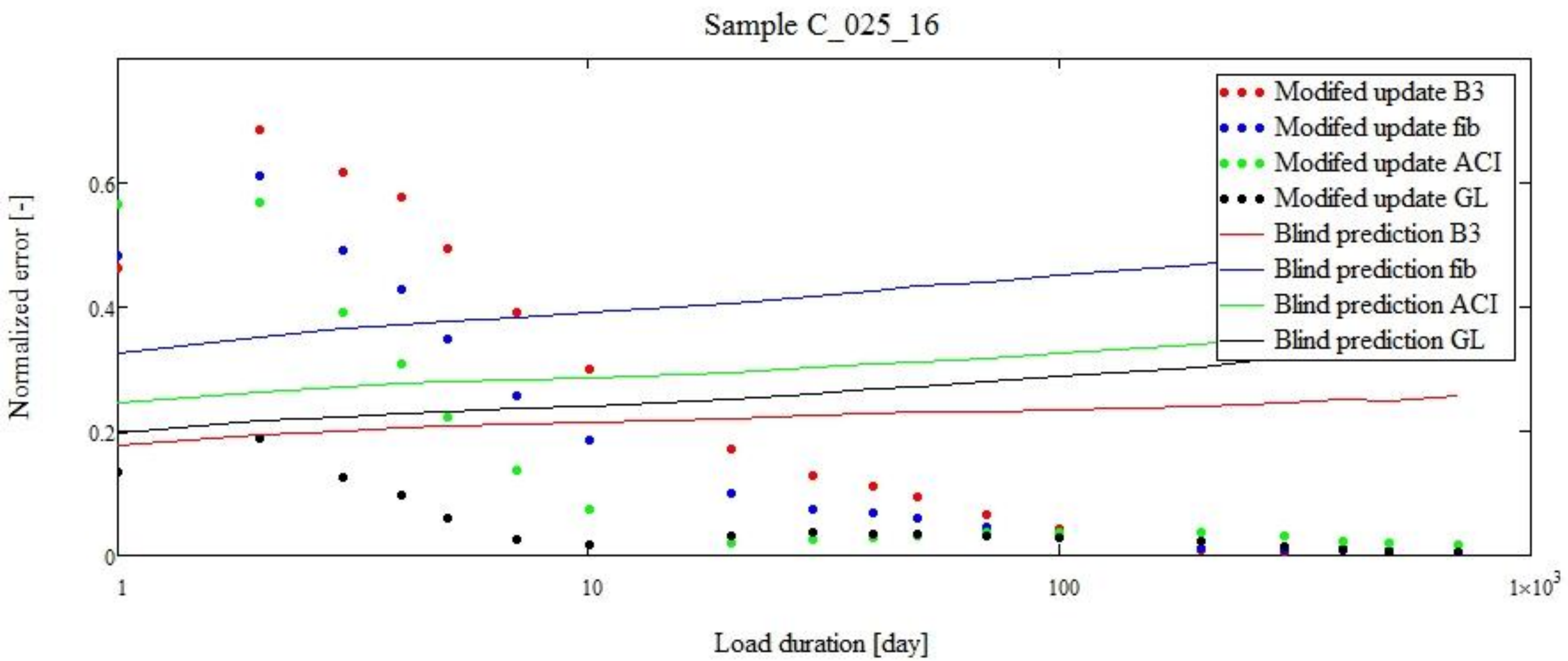


Optimal time for short-time data x Minimal time for short-time data

Optimal time for short-time data



Minimal time for short-time data

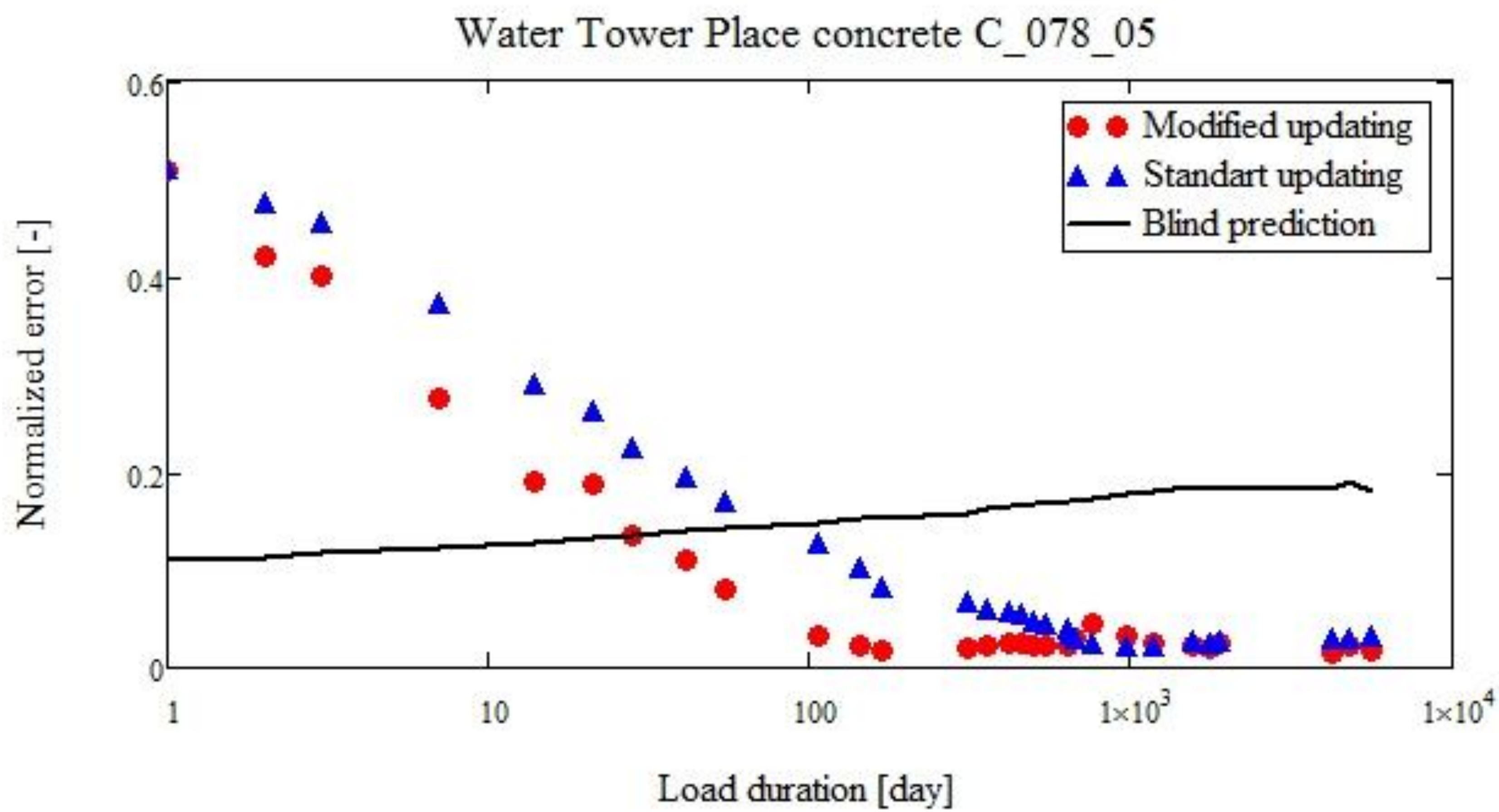


Model	Load duration [day]	Number of measurements
B3 Model	48,7	4,65
Fib Model	59,1	4,25
ACI Model	58,0	5,48
GL Model	18,6	2,38

Conclusions

- Using weight factor of load duration
- Measuring times
  - Essential: 2 months (B3, fib, ACI)
  - Optimal: 12 months
    - Improvement about 85% compare to „blind“ prediction
    - Possible improvement 80%
- Recommendations:
  - Do not use „short-time dates“ measured till 24 hours after loading
    - (improving convergence)

Conclusions



Acknowledgments

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Thank you for your attention

Discussion