

Expressions obtained in applications 5.5 and 6.4 are detailed in this section. They are shown in the same format as they were generated by the genetic programming algorithm.

A.1 Recognition of damage in steel structures

A.1.1 Approximation of the overall expression with 20 points

$$\begin{aligned} \tilde{F}(\mathbf{x}) = & (0.039090 + ((((-0.206028 * X3) + (((((((((((24163.012060 * X2) + \\ & (434044.958979 * ((X3 * (X2 / (X2 * X1))) / X2))) + (-5299.828061 * X1)) / X1 \\ & + (-387.122363 * X2)) + (84.102866 * X1)) / X2) + (0.002497 * (X3 * X1))) + \\ & (9369129.994005 * (X1 / ((X1 * X2))^2))) + (-90.525544 * (((X2 * X2) * ((X2 / \\ & X2) / X1)) / X2))) + (-17552435.304601 * (X2 / ((X1 * X2))^2))) + \\ & (647985.936027 * (X1 / ((X3 * X2))^2))) / (X1 * X2)) + (((-0.000002 * X2) + (((- \\ & 0.000094 * X1) + (0.000142 * X2) / X2)) * X1))) \end{aligned} \quad (\text{A.1})$$

A.1.2 Approximation of the overall expression with 50 points

$$\begin{aligned} \tilde{F}(\mathbf{x}) = & (0.003431 + (((((X2 / X2) / X3) / X3) / X2) * ((((((((-320.218074 * X2) + \\ & (3692605.078173 * ((X2 / X3) / X3))) / X3) / X3) + (-34.172610 * (X2 / X2))) + \\ & (((((X2 / X2) / X1) / X3) / (((X3 / ((X2 / X2) / X1)) / X3) / X1) / X3)) * (((((- \\ & 0.077802 * X1) + (0.569689 * X2)) + (((((((254.537900 * ((X3 * X3) / X1)) + \\ & (((163409700.493759 * (X2 / X1)) + ((-119715870.966139 * X2) + \\ & (181906714.421767 * X3))) / X2) / X2) / X3)) + (6477.448522 * (X2 / X1))) + (- \\ & 1265.055170 * X3)) / X2) + (51057.139842 * ((X2 / X3) / X3))) / X1)) / (X2 / \\ & X1)) + (-0.223793 * X2) * X3))) * X3)) + (80990447.005137 * (((((((X3 / X3) / \\ & X1) / X3) / X1) / X1) / X1) / X1))) \end{aligned} \quad (\text{A.2})$$

A.1.3 Approximation of the individual frequencies with 20 points

$$\begin{aligned} \tilde{\omega}_1^a(\mathbf{x}) = & (10.386341 + (((((2.837879 * X3) + (((-2.937147 * (((X3 * X2) / X1) / \\ & X1) * X3)) + ((-270.654529 * X3) + (2771.051960 * (X3 / X1)))) / X1)) + \\ & (\text{sqrt}(X3) * (((0.736986 * X3) + ((-1)*(X3) * ((-0.000000 * ((X3 * X2) * X1)) + \\ & ((0.003801 * X3) + (X2 * (((((0.000035 * X3) + (-0.000010 * X1)) * X1) + ((- \\ & 0.001637 * X3) + (0.004911 * (X2 / X3)))) / X1)))))) + (-0.315644 * X1))) / X1 \\ & + ((((-0.000002 * (X1 * X3)) + (0.000340 * X1)) * X3))) \end{aligned} \quad (\text{A.3})$$

$$\begin{aligned} \tilde{\omega}_2^a(\mathbf{x}) = & (10.424778 + (((((-0.000167 * X3) + ((-0.002479 * X2) + (((0.000036 * \\ & (X2 / (X1 / (X1 / X1)))) + ((-0.000000 * ((X1 / X3) * X2)) + (0.000009 * X2))) * \\ & X2)) * X2) + (0.181080 * X2)) + ((X1 * ((-0.000009 * (X1 * X2)) + (0.000385 * \\ & X3))) + (((0.007548 * ((X3 / X2) / X2)) + ((0.000118 * X1) + (-0.125083 * ((X2 / \\ & X1) / X1)))) * X1)) + (X1 * ((X1 * ((-0.000003 * X3) + (-0.000000 * ((X1 / X3) * \\ & X2))) + (0.001319 * X2)))))) \end{aligned} \quad (\text{A.4})$$

$$\begin{aligned} \tilde{\omega}_3^a(\mathbf{x}) = & (47.266406 + (((-1)*((-0.008277 * X3)) + (((((13.318167 * X3) + (- \\ & 229.556660 * X1)) + (-0.000000 * (((X3)**2)**2 * X1))) / (X1)**2) + (-0.020792 \\ & * X1))) + ((X3 * ((638184.853093 * (\text{sqrt}((X1 / X1)) / X2)) + (((((- \\ & 1845663.342900 * (X2 / X1)) + (-1341334.528574 * X3)) + (-1337841.052320 * \\ & X1)) + ((8259433.630561 * (X3 / X1)) + ((((-106759670428.801498 * (X2 / X3)) \\ & + (-1195733535.621303 * X3)) / (X2)**2) + (34934656.177788 * X1)) / X1))) / \\ & (X1)**2) + (182.170051 * X2)))) / (X3 * ((-1)*((X3)**2 * X1)))) \end{aligned} \quad (\text{A.5})$$

$$\begin{aligned} \tilde{\omega}_4^a(\mathbf{x}) = & (530.854567 + (((((X2 / \text{sqrt}(X2)) * ((((-0.000039 * ((X2 / ((X1)^2 / (- \\ & 1)*(X1))) / (X2 / (X2 / (X1 / (-1)*((X3)^2)))))) + ((0.170021 * X2) + (-1)*((- \\ & 0.003545 * (X2 / X3)))))) + (-0.000001 * (X2 / (X1 / (-1)*((X3)^2)))))) + (- \\ & 1)*(((11753.656532 * (X2 / X2)) + (3835.469921 * X2)) / (X2)^2))) + \\ & (11326.306964 * (X2 / (X2)^2))) + ((-3.474308 * X2) + (-1)*((((((0.000052 * \\ & ((X3)^2 / (-1)*(((X2 / X2) / X2) / \text{sqrt}(X2)))))) + ((-1)*((-2397.467497 * (X2 / \\ & (X2)^2)) + (-5160922.109400 * (X2 / ((X2)^2)^2))) + (-0.851587 * X3)) * (- \\ & 1)*(((X2 / (X3)^2)^2) + ((0.021987 * X1))^2) + (-0.089465 * X1)))))) \end{aligned} \quad (\text{A.6})$$

A.1.4 Approximation of the individual frequencies with 50 points

$$\begin{aligned} \tilde{\omega}_1^a(\mathbf{x}) = & (5.460544 + (((0.000007 * (X1 * X1)) + ((0.171302 * X3) + ((((-1)*(((\\ & -1)*((-1)*((((-39676.679754 * X1) + (((X3 * \text{sqrt}(X1)))^2 / \text{sqrt}(X1)) * \\ & ((48.756114 * ((-1)*(X1) / (X1 * \text{sqrt}(X1)))))) + (X1 * ((-0.560380 * (X1 / (X1 * \\ & \text{sqrt}(X2)))) + (0.009956 * (X1 * X1)))))) + (0.628649 * X1)))) + \\ & (((4535287.764232 * (X1 / (X1 * (X2)^2))) + (-138.425092 * (X1 * X1))) + \\ & (3938.118530 * X1)) * X1))) + (2796.796107 * (X1 * (-1)*((X3 / X1)))) / ((X1 * \\ & X3) / \text{sqrt}(X3))) + (154.571334 * X1))) + (-0.000009 * ((X1 * ((X3 * \text{sqrt}(X1)))^2 \\ & * X1)) / (X1 * X1)) / \text{sqrt}(X1)))) \end{aligned} \quad (\text{A.7})$$

$$\begin{aligned} \tilde{\omega}_2^a(\mathbf{x}) = & (8.973018 + ((((((0.000188 * X1) + (((0.000006 * X3) + (-0.000040 * \\ & X1)) * (-1)*((-1)*(sqrt(X2)))) + (0.001281 * X2))) + (-1)*(((88.740847 * X3) + \\ & ((0.000554 * X2) + (0.000321 * X1))) / X3))) * X1 + ((96.596446 * X1) + (((- \\ & 1)*((-1)*((-0.040109 * X2))) + (((-1)*((-0.000107 * X2)) + (-1)*((-1)*((-0.000080 \\ & * X1)))) * X2)) * sqrt(X2)) + ((-7.804551 * X1) + (-1)*((-0.341727 * X2)))))) + (- \\ & 1)*((-1)*((-1)*((-1)*((-0.000175 * X3)))))) \end{aligned} \quad (\text{A.8})$$

$$\begin{aligned} \tilde{\omega}_3^a(\mathbf{x}) = & (51.708011 + ((((((0.025243 * X2) + ((-0.246981 * (X1 * X1)) + ((X1 / \\ & X3) * ((6.267066 * (X1 / X1)) + (0.225265 * X1)))))) + ((((-0.060765 * X1) + ((- \\ & 0.000373 * (X3 * X1)) + (11.439241 * (((-1)*(X1) / (X1 / sqrt(X1))) / (X3^2)))) + \\ & (0.010829 * X3)) * X1) / sqrt(X3))) + (((-10.315803 * X1) + (-0.002011 * \\ & ((sqrt(X3) * (X1 / sqrt(X3))) / sqrt(X2)) * X1))) + (-1.426908 * ((X1 / X3) * X1 \\ & / sqrt(X1)))) / sqrt(X1)) + (0.008537 * (X1 * X1)) + ((2.643684 * X1) + (- \\ & 0.004290 * X2))) \end{aligned} \quad (\text{A.9})$$

$$\begin{aligned} \tilde{\omega}_4^a(\mathbf{x}) = & (69.851380 + (((((-0.000418 * (X1 * X1)) + (((-0.077447 * (X2 / X1)) + \\ & (((0.002794 * X1) + ((3.865279 * X2) + ((((-0.000034 * X1) + (((-70.561782 * \\ & X2) + (-0.000035 * (X2 * X2))) + ((-0.000001 * (X3 * (X2 / X1))) + (-4.058900 * \\ & (X2 / (((X2 * X3) * X3) * (X3 * (X2 / X1))))))))) + (0.058026 * (sqrt(X2) / (X1 * \\ & X1))) * X2))) + (70.591605 * (X2 * X2))) * sqrt(X2))) + (-9.588372 * X2) + (- \\ & 0.553781 * (X2 * X2)) + (0.069385 * X1)) \end{aligned} \quad (\text{A.10})$$

A.2 Multicriteria optimization of the calcination of Roman cement

A.2.1 Anhydrite

$$\begin{aligned} \tilde{F}(\mathbf{x}) = & (69260.38106884244189 + ((((-350.2331641871767829 * X2) + ((((- \\ & 1310.570478908714904 * X1) + (((5598.461863883710066 * (X2 / X2)) + \\ & (((0.009363030167179001162 * X2) + ((-2.692289315699507579 * (X2 / X1)) + \\ & (-18.92464918845228539 * (X2 / sqrt((X2 * X1)))))) * X2)) * X2)) + \\ & (((((35645285715.33451843 * (X2 / X2)) + (-614621078.3899461031 * X2)) + (- \\ & 47546988.4624280259 * X1)) / X1) / X2)) / sqrt(X1))) + (427.6131272813685769 \\ & * (X2 * ((X2)**2 / X2)) / X1)) + (0.1006557654148574621 * (X2 * X1))) \end{aligned} \quad (\text{A.11})$$

A.2.2 Gehlenite

$$\begin{aligned} \tilde{F}(\mathbf{x}) = & (-8411.090320411742141 + (((60144.5040534966538 * ((X1 / X1) / \\ & X1)) + (((100625.3176885498542 * ((X2 / X1) / X1)) + \\ & (0.7155981364592249871 * X2)) + (-5.50591382533312057 * (X1 / X1))) + (- \\ & 0.06592100166172433495 * X1))) * X2 + (((X2)**2 * ((-764.240629739607698 \\ & * ((X1 / X1) / X1)) + (((0.8251996718748132453 * (X2 / X1)) + (- \\ & 0.0009188630134374352072 * X2)) + (6.006453208504369678e-06 * X1)))) + \\ & (9.21357151651476336 * X1))) \end{aligned} \quad (\text{A.12})$$

A.2.3 Larnite

$$\begin{aligned} \tilde{F}(\mathbf{x}) = & (-94581.87235497981601 + (((((0.005175938479240709336 * (\text{sqrt}(X2) * \\ & X2)) + (1.071947512944761094 * X1)) * X2) + ((((\text{sqrt}(X1) / X2) * ((- \\ & 73.09921176499319984 * X1) + (X2 * ((-0.6550637534272812923 * (\text{sqrt}(X2) * \\ & X2)) + ((-10.05286026995448267 * X1) + (0.001810223234395569271 * (X1 * \\ & X1)))))) + (492.6966986241965287 * X1)) + ((\text{sqrt}(X2) * ((- \\ & 21.39451287200024865 * X1) + (-0.008675216760697445489 * (X2 * X1)))) + \\ & (213.8104839315043648 * X2)))))) \end{aligned} \quad (\text{A.13})$$

A.2.4 Loss on calcination

$$\begin{aligned} \tilde{F}(\mathbf{x}) = & (-2786.108595626706119 + ((((((0.03822296963097596145 * X2) + \\ & (((0.0005294153570942569274 * (X1 / \text{sqrt}(\text{sqrt}((X2)**2)))) + (((- \\ & 0.001514264155572610758 * (\text{sqrt}(X2) * X1)) + ((0.01130305108589140309 * \\ & (\text{sqrt}(((\text{sqrt}(X1) / X1) * X2)) * X1)) + ((4.086901378462313459e-06 * (X1 * X1)) \\ & + (-0.4863865144211507174 * (X2 / \text{sqrt}(\text{sqrt}((X2)**2)))))) + (- \\ & 3257.437983783903292 * ((X2 / X1) / X1))) + (-0.01098184552148428507 * \\ & X1)) * X1) + (47.76790363626044211 * X2)) + (-2.62368092236100825 * \\ & (\text{sqrt}(X1) * X2)) + (9.58900618936983129 * X1)) \end{aligned} \quad (\text{A.14})$$

A.2.5 Silica

$$\begin{aligned} \tilde{F}(\mathbf{x}) = & (565.7552106637665474 + ((((((10343.52925057315952 * X1) + (- \\ & 223666.3107877066359 * X2)) / X2) + (((((-4632243960172.693359 * (X1 / X1)) \\ & + (194524599092.2554321 * X2)) / X2) + (-1191157292.471004725 * X2)) / X1) / \\ & X1) / X2) + ((0.2911660034247788298 * X1) + (((((-68356.34459323658666 * \\ & X1) + ((((-6760998744105.896484 * (X1 / X1)) + (30618899847.98148346 * \\ & X1)) / X2) + (-125613434.5109226406 * X2)) / X1)) / X2) + \\ & (444.7933237429991209 * X2)) / ((X1 * ((X1 / X2) / X2)**2)))) \end{aligned} \quad (\text{A.15})$$

A.2.6 Rate of strength enhancement

$$\begin{aligned} \tilde{F}(\mathbf{x}) = & (-43802.4893453933837 + ((9060698.851935477927 * (X2 / (X2 * X1))) \\ & + (((((-1240.299385992319912 * X2) + (X1 * ((0.001344456865273283095 * (X1 \\ & * X2)) + (-4.115575008160428538 * X1)))) / \text{sqrt}(X1)) + \\ & ((80.22046006086138448 * X2) + ((X1 * ((-0.08352442231088581803 * X2) + \\ & (0.03940527582626181941 * X1))) + (-9238.203609954107378 * (X1 / (X2 * \\ & ((X1 * X2) / X2) * X2)))))) + (125.4856519857496409 * X1)) \end{aligned} \quad (\text{A.16})$$

A.2.7 Setting

$$\begin{aligned} \tilde{F}(\mathbf{x}) = & (147691.6590329107712 + ((0.0007505200383469901515 * ((X1)**2 * \\ & X2)) + ((-932.8729053806877118 * (((X1 * (X1 / X1)) / X1) * X1)) + (((((- \\ & 0.002643991412151242004 * X2) + (((8.711034023765318381e-06 * X2) + (- \\ & 4.364400036115123434e-06 * X1)) * X2) + (-4.261617802829133161 * X1))) * \\ & X2) + (-2016.622162362330755 * X2)) + ((0.01319367731791244204 * ((X1)**2 \\ & / X2)) + (-0.4903854046045609816 * (((X1 * X2) / X2) * X1)))) + \\ & (((174.8676609652199261 * X2) + (40.32851258099314151 * X1)) * \text{sqrt}(X1)))) \end{aligned} \quad (\text{A.17})$$

A.2.8 Strength at 1 week

$$\begin{aligned} \tilde{F}(\mathbf{x}) = & (-169.9588430395384933 + (((0.3877088489500533086 * X1) + (- \\ & 0.01749577797988736277 * (X2 * X1))) + ((X1 * ((X2 * \\ & (((215882974.8222336471 * X1) + (-166501.8709735501907 * (X2 * X1))) + \\ & ((X1 * (((4822453218.254610062 * (((X2 / X1) / X1) * X1)) + \\ & (15347084.72772874311 * X2)) + (-7116881.105396197177 * X1))) / \\ & (\text{sqrt}(\text{sqrt}(X1)))**2)) + (-471305448.1577598453 * X2))) + (- \\ & 37264191058.90937042 * X2)) / ((X1)**2)**2)) + ((- \\ & 0.0002129577905037445768 * (X1 * X1)) + (63.91882372002105939 * X2))) \end{aligned} \quad (\text{A.18})$$