

AC Modulus vs. Temperature: Lab vs. Field

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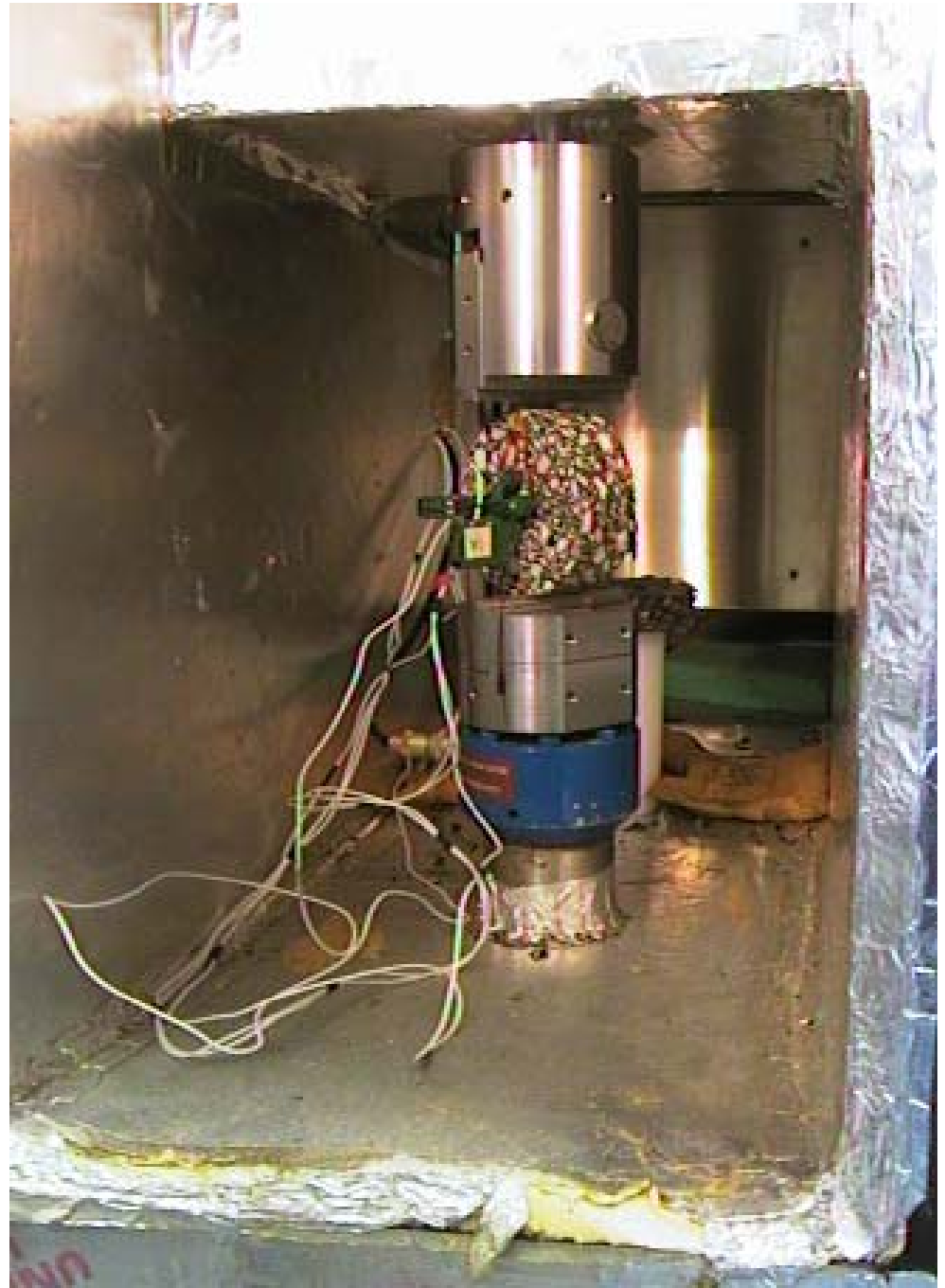


Data Source

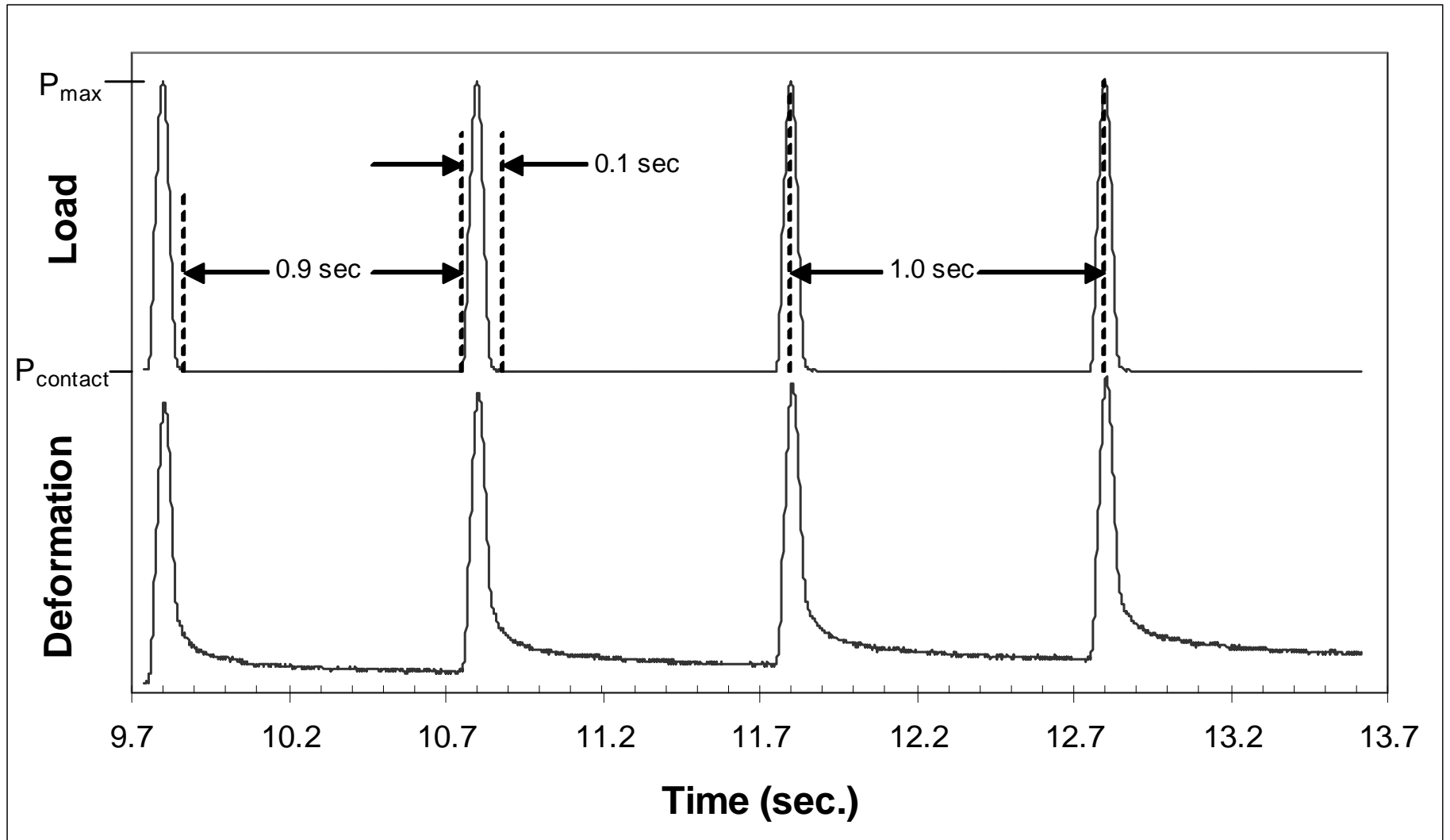
- LTPP Seasonal Monitoring Program (SMP)
 - FWD Testing in a wide range of temperatures, backcalculation performed in previous study
 - Laboratory AC Resilient modulus testing (P07)
- 31 SMP sites with sufficient FWD and P07 data for comparison purposes

LTPP P07 Test

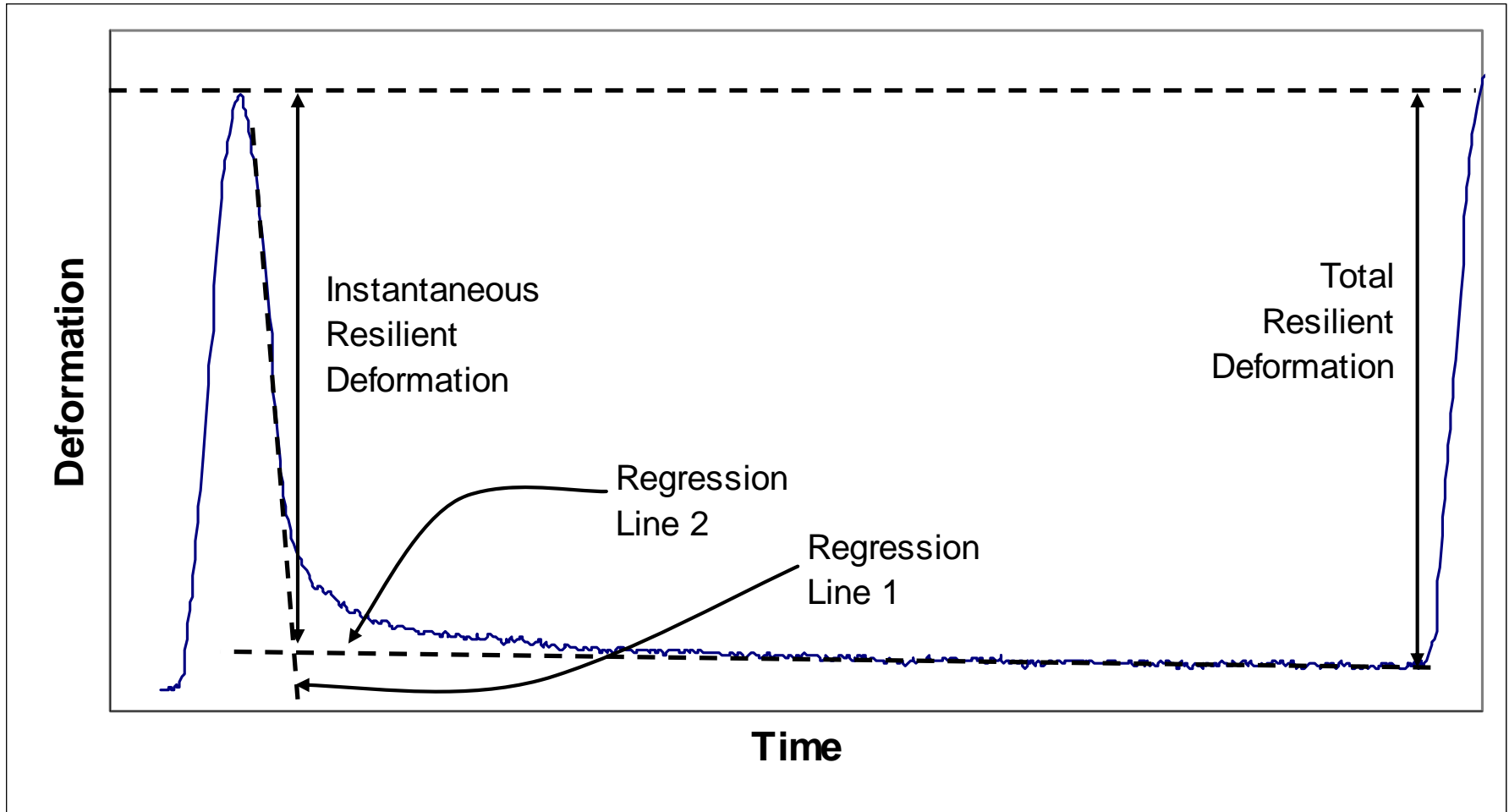
- **4" Cores**
- **Indirect Tension**
- **M_r , Creep
Compliance,
Tensile Strength**
- **3 Temperatures**
5°, 25°, 40° C
- **3 Cores**
Results of all cores
are combined



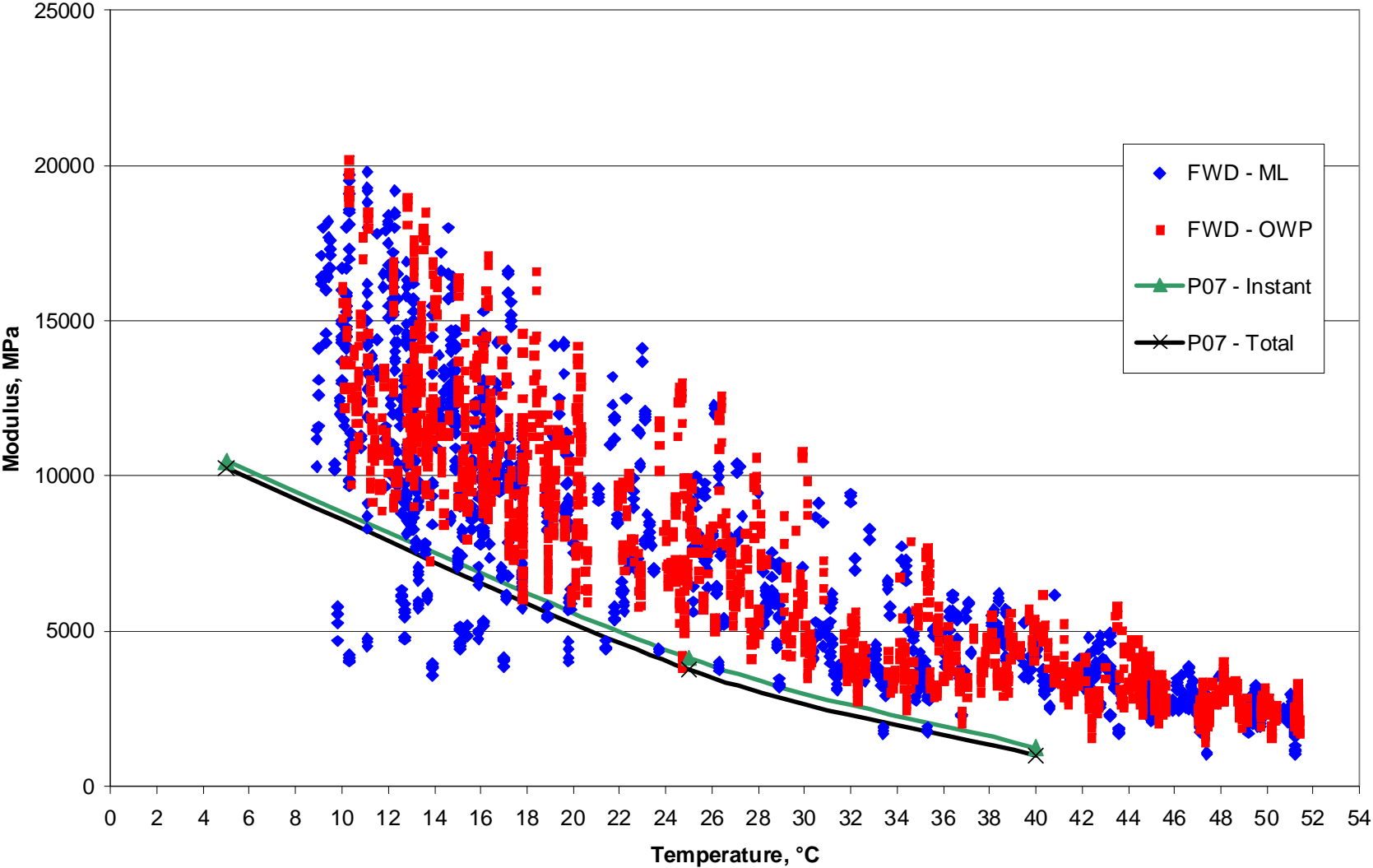
P07: M_r Loading



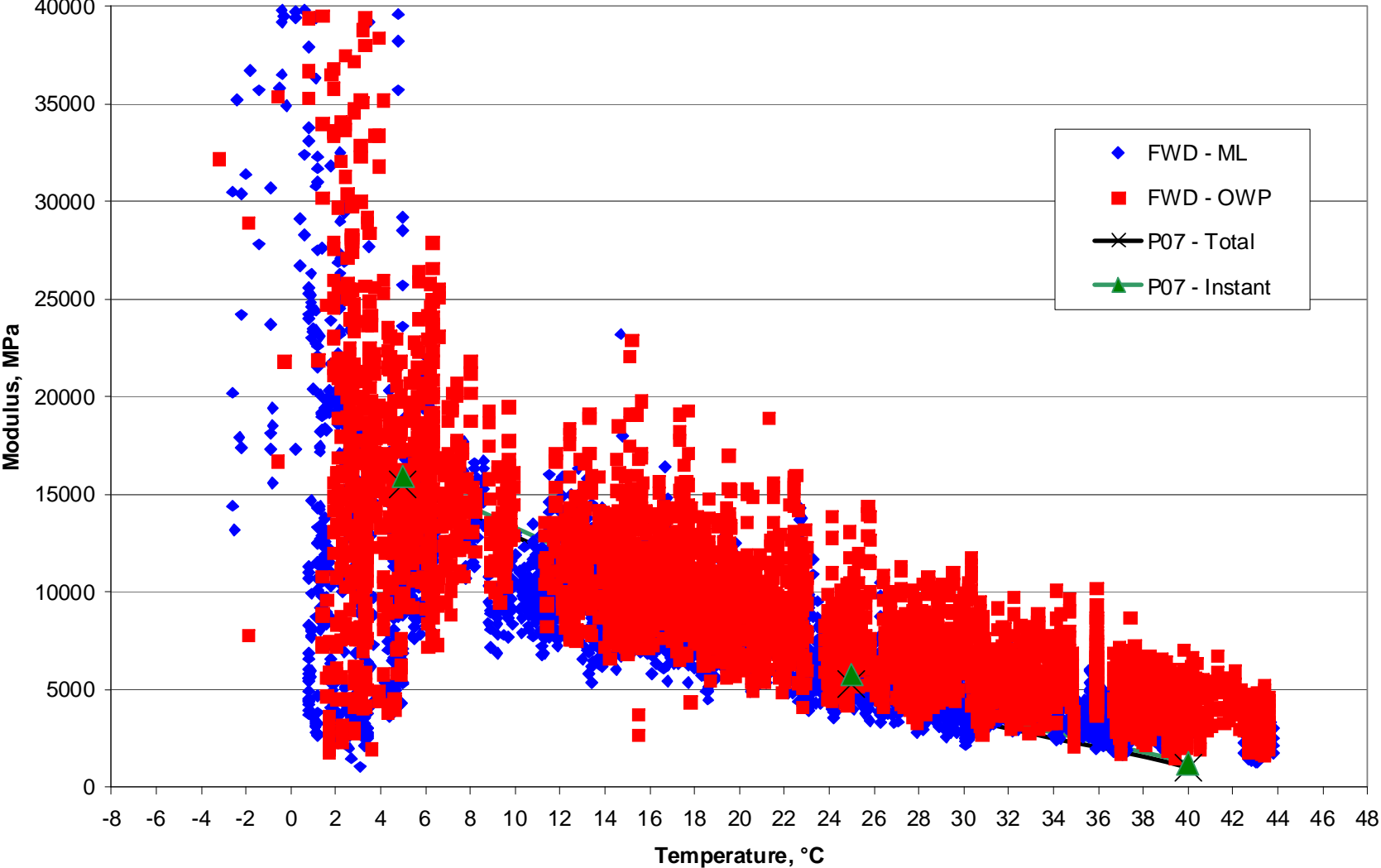
P07: M_r Calculations



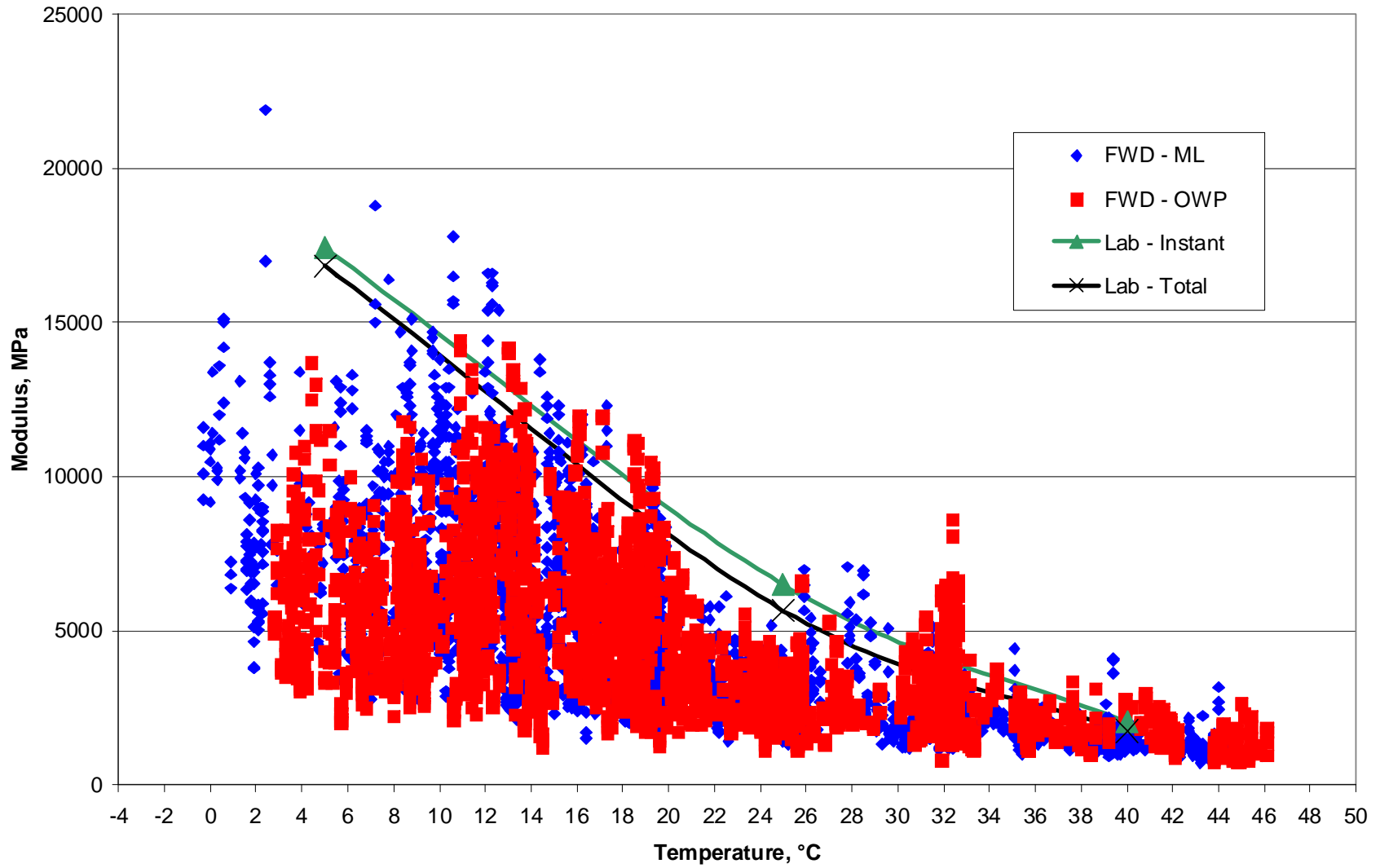
Section 040113



Section 308129



Section 081053



Modulus vs. Temperature Regression Equation

$$E_{ref} = E_{test} \times 10^{k(T_{ref} - T_{test})}$$

- Used by MODTAG
- k values developed by Lukanen, Stubstad and Briggs in FHWA-RD-98-085
 - 0.0195 for Wheel Path
 - 0.021 for Mid Lane

Regression Results: FWD ML

| Section | E ₀ , MPa | k | R ² |
|---------|----------------------|---------|----------------|
| 040113 | 19312 | -0.0183 | 0.7671 |
| 040114 | 19688 | -0.0064 | 0.929 |
| 041024 | 10559 | -0.0281 | 0.8195 |
| 081053 | 11340 | -0.0224 | 0.6709 |
| 091803 | 14588 | -0.0170 | 0.666 |
| 131005 | 29079 | -0.0240 | 0.9341 |
| 131031 | 8478 | -0.0257 | 0.876 |
| 231026 | 18102 | -0.0280 | 0.8101 |
| 241634 | 7557 | -0.0188 | 0.2336 |
| 251002 | 9462 | -0.0229 | 0.7998 |
| 271018 | 13891 | -0.0162 | 0.4912 |
| 271028 | 26035 | -0.0057 | 0.0223 |
| 276251 | 10533 | -0.0191 | 0.382 |
| 281016 | 29117 | -0.0235 | 0.9296 |
| 281802 | 17269 | -0.0118 | 0.7691 |
| 308129 | 24430 | -0.0250 | 0.5915 |

| Section | E ₀ , MPa | k | R ² |
|---------|----------------------|---------|----------------|
| 331001 | 13968 | -0.0175 | 0.9015 |
| 351112 | 34982 | -0.0273 | 0.9101 |
| 371028 | 18478 | -0.0284 | 0.2087 |
| 404165 | 16420 | -0.0094 | 0.0429 |
| 460804 | 15187 | -0.0411 | 0.7751 |
| 481060 | 36296 | -0.0205 | 0.7603 |
| 481068 | 12628 | -0.0239 | 0.8991 |
| 481077 | 21134 | -0.0289 | 0.8173 |
| 481112 | 19438 | -0.0261 | 0.5804 |
| 483739 | 27944 | -0.0026 | 0.0132 |
| 491001 | 16895 | -0.0122 | 0.3543 |
| 501002 | 16183 | -0.0336 | 0.895 |
| 561007 | 15322 | -0.0157 | 0.2463 |
| 831801 | 9372 | -0.0241 | 0.178 |
| 906405 | 15043 | -0.0143 | 0.2296 |

Regression Results: FWD OWP

| Section | E_0 , MPa | k | R^2 |
|---------|-------------|---------|--------|
| 040113 | 16602 | -0.0192 | 0.8762 |
| 040114 | 21998 | -0.0219 | 0.9236 |
| 041024 | 20852 | -0.0301 | 0.8044 |
| 081053 | 8642 | -0.0172 | 0.481 |
| 091803 | 13770 | -0.0155 | 0.4787 |
| 131005 | 25778 | -0.0243 | 0.8941 |
| 131031 | 7200 | -0.0195 | 0.7581 |
| 231026 | 19593 | -0.0276 | 0.8664 |
| 241634 | 11505 | -0.0225 | 0.3022 |
| 251002 | 10421 | -0.0216 | 0.7138 |
| 271018 | 17257 | -0.0164 | 0.367 |
| 271028 | 56637 | 0.0094 | 0.0893 |
| 276251 | 13751 | -0.0182 | 0.5011 |
| 281016 | 27717 | -0.0222 | 0.9389 |
| 281802 | 17735 | -0.0135 | 0.7533 |
| 308129 | 31622 | -0.0244 | 0.5853 |

| Section | E_0 , MPa | k | R^2 |
|---------|-------------|---------|--------|
| 331001 | 11684 | -0.0144 | 0.663 |
| 351112 | 34478 | -0.0270 | 0.8964 |
| 371028 | 5003 | -0.0066 | 0.0097 |
| 404165 | 39222 | -0.0161 | 0.0956 |
| 460804 | 14690 | -0.0493 | 0.8668 |
| 481060 | 33148 | -0.0202 | 0.667 |
| 481068 | 10489 | -0.0200 | 0.6435 |
| 481077 | 19608 | -0.0210 | 0.7939 |
| 481112 | 19197 | -0.0225 | 0.4973 |
| 483739 | 19902 | -0.0028 | 0.0207 |
| 491001 | 18253 | -0.0169 | 0.6479 |
| 501002 | 21641 | -0.0350 | 0.8866 |
| 561007 | 9534 | -0.0151 | 0.3828 |
| 831801 | 12373 | -0.0265 | 0.4684 |
| 906405 | 13880 | -0.0106 | 0.1274 |

Regression Results: Lab Instantaneous M_r

| Section | E_0 , MPa | k | R^2 |
|---------|-------------|---------|--------|
| 040113 | 15316 | -0.0260 | 0.9763 |
| 040114 | 15316 | -0.0260 | 0.9763 |
| 041024 | 16174 | -0.0257 | 0.9956 |
| 081053 | 25274 | -0.0263 | 0.9833 |
| 091803 | 37461 | -0.0317 | 0.9984 |
| 131005 | 23603 | -0.0225 | 0.9755 |
| 131031 | 15552 | -0.0305 | 0.9948 |
| 231026 | 18819 | -0.0329 | 0.9857 |
| 241634 | 19502 | -0.0337 | 1 |
| 251002 | 17945 | -0.0241 | 0.9737 |
| 271018 | 13643 | -0.0323 | 0.9976 |
| 271028 | 23228 | -0.0229 | 0.9576 |
| 276251 | 25288 | -0.0317 | 0.9694 |
| 281016 | 19898 | -0.0186 | 0.9946 |
| 281802 | 22110 | -0.0180 | 0.9895 |
| 308129 | 25967 | -0.0314 | 0.9605 |

| Section | E_0 , MPa | k | R^2 |
|---------|-------------|---------|--------|
| 331001 | 22284 | -0.0231 | 0.9844 |
| 351112 | 28400 | -0.0281 | 0.9817 |
| 371028 | 27128 | -0.0297 | 0.9984 |
| 404165 | 27059 | -0.0246 | 0.9611 |
| 460804 | 15574 | -0.0363 | 0.9498 |
| 481060 | 26647 | -0.0193 | 0.9886 |
| 481068 | 21604 | -0.0291 | 0.979 |
| 481077 | 16346 | -0.0238 | 0.998 |
| 481112 | 25715 | -0.0213 | 0.972 |
| 483739 | 16982 | -0.0179 | 0.9483 |
| 491001 | 31033 | -0.0305 | 0.9534 |
| 501002 | 24305 | -0.0400 | 0.9675 |
| 561007 | 18346 | -0.0230 | 0.9957 |
| 831801 | 15900 | -0.0294 | 0.9952 |
| 906405 | 21871 | -0.0260 | 0.9897 |

Regression Results: Lab Total M_r

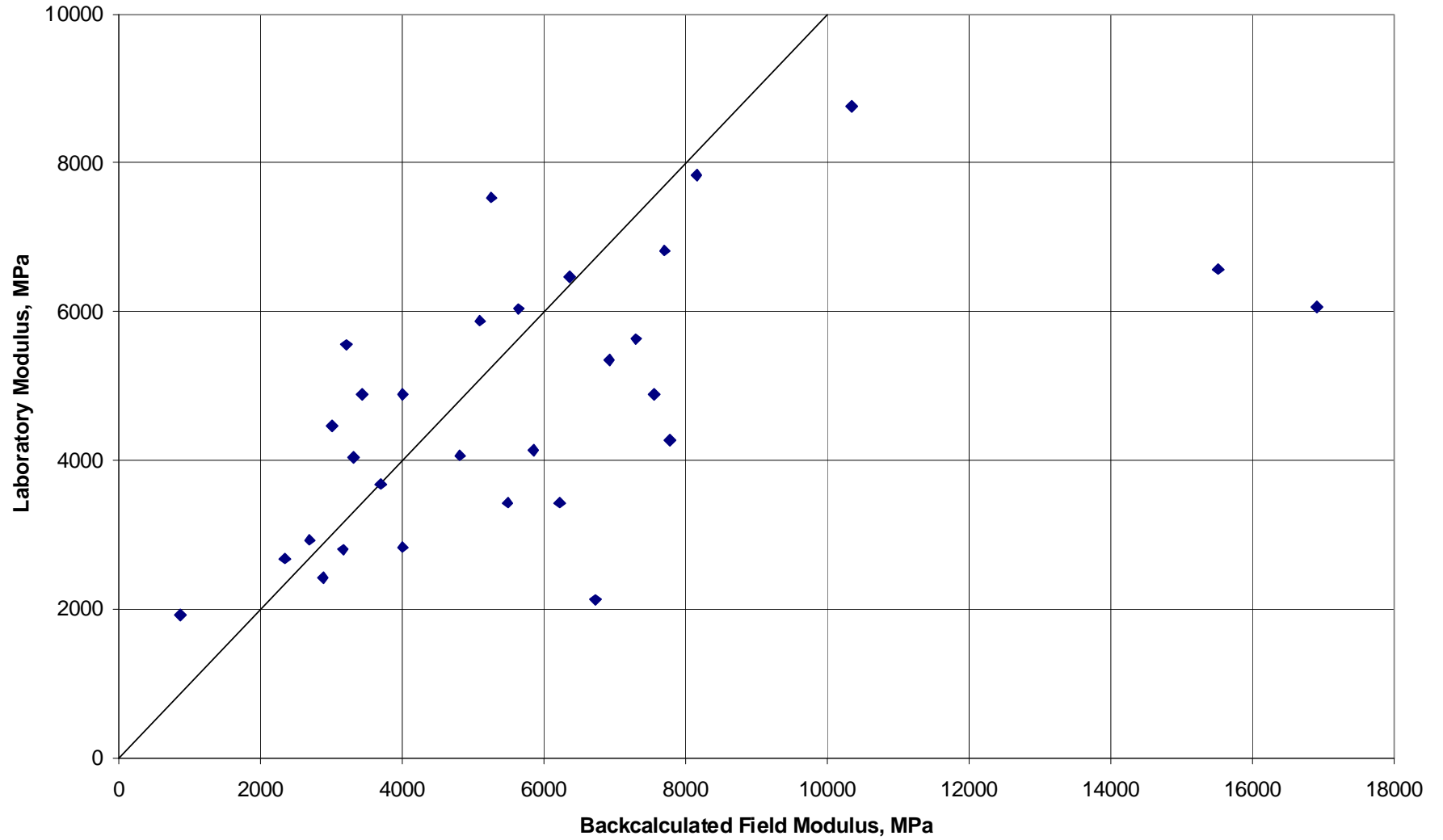
| Section | E_0 , MPa | k | R^2 |
|---------|-------------|---------|--------|
| 040113 | 15605 | -0.0284 | 0.9739 |
| 040114 | 15605 | -0.0284 | 0.9739 |
| 041024 | 15812 | -0.0276 | 0.9974 |
| 081053 | 24586 | -0.0278 | 0.9893 |
| 091803 | 35059 | -0.0285 | 0.9997 |
| 131005 | 23795 | -0.0241 | 0.9733 |
| 131031 | 15115 | -0.0321 | 0.9957 |
| 231026 | 18205 | -0.0347 | 0.9912 |
| 241634 | 18508 | -0.0352 | 0.9982 |
| 251002 | 17834 | -0.0258 | 0.9744 |
| 271018 | 13238 | -0.0338 | 0.9989 |
| 271028 | 23436 | -0.0245 | 0.9575 |
| 276251 | 24974 | -0.0340 | 0.9739 |
| 281016 | 19838 | -0.0198 | 0.9933 |
| 281802 | 21633 | -0.0153 | 0.959 |
| 308129 | 25981 | -0.0331 | 0.9594 |

| Section | E_0 , MPa | k | R^2 |
|---------|-------------|---------|--------|
| 331001 | 21650 | -0.0231 | 0.986 |
| 351112 | 28704 | -0.0304 | 0.9804 |
| 371028 | 21440 | -0.0318 | 0.9986 |
| 404165 | 27447 | -0.0266 | 0.9604 |
| 460804 | 14969 | -0.0383 | 0.9508 |
| 481060 | 26724 | -0.0211 | 0.9873 |
| 481068 | 21286 | -0.0311 | 0.9787 |
| 481077 | 16009 | -0.0256 | 0.9978 |
| 481112 | 26380 | -0.0244 | 0.9672 |
| 483739 | 16616 | -0.0188 | 0.9506 |
| 491001 | 31935 | -0.0341 | 0.9552 |
| 501002 | 23476 | -0.0429 | 0.9693 |
| 561007 | 18338 | -0.0250 | 0.9949 |
| 831801 | 15685 | -0.0317 | 0.9963 |
| 906405 | 21233 | -0.0272 | 0.995 |

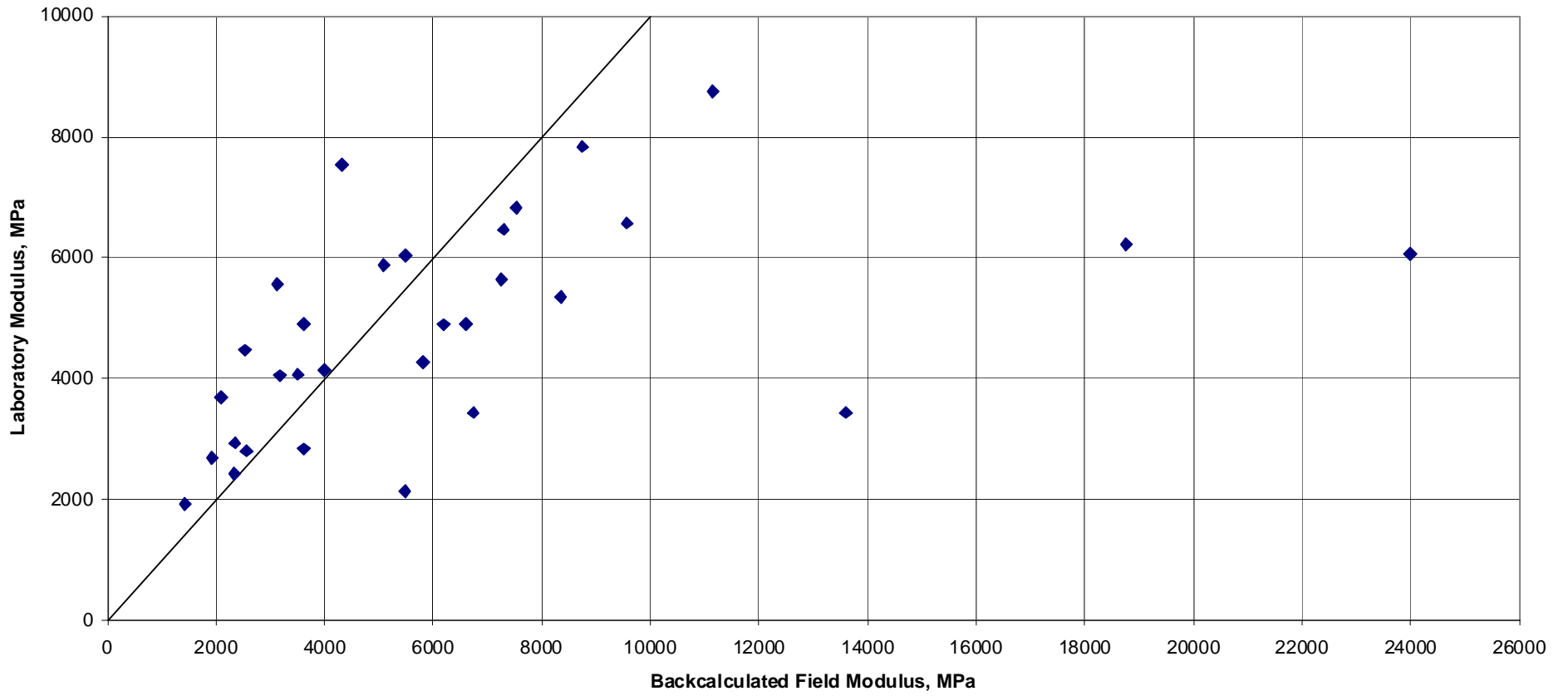
Average k Values

| | All Sections | $R^2 > 0.5$ | Lukanen et al. |
|---------------|------------------|------------------|------------------|
| FWD – ML | -0.0206 (n = 31) | -0.0236 (n = 20) | -0.021 (n = 25) |
| FWD – OWP | -0.0196 (n = 31) | -0.0235 (n = 19) | -0.0195 (n = 25) |
| Lab – Instant | -0.0270 | | |
| Lab – Total | -0.0286 | | |

FWD OWP vs Lab Instantaneous at 25C



FWD ML vs Lab Instantaneous at 25C



Conclusions

- k values published by Lukanen et al. and used by MODTAG appear reasonable
- P07 test is slightly more temperature sensitive than FWD
- Any systematic difference between P07 and FWD is masked by spatial variability and/or random error