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SPECIAL PROJECT REPORT

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FINAL REPORT ON THE INVESTIGATION OF CRACKS AT SHEK WU HUI TREATMENT PLANT

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FOREWORD

In mid-1991, at the request of the Standing Committee on Concrete Technology (SCCT), the Public Works Central Laboratory (PWCL) of the Materials Division carried out an investigation into the extensive cracking of concrete in the sedimentation and aeration tanks at the Shek Wu Hui Sewage Treatment Plant.

The early stage planning of this investigation was carried out by Mr. P.C. Wong who prepared an interim report on this investigation with Mr. N.P. Koirala in July 1992. Mr. W.C. Leung took over the management of the project in January 1993. Mr. W.L. Tse, who supervised the site monitoring works and the core expansion tests, prepared this report together with Mr. S.T. Gilbert, who carried out the petrographic examinations. The site monitoring and thin section preparation were carried out by the technical staff of the PWCL. In particular, Ms K.Y. Law carried out the core expansion tests. Finally, the Survey Division of the Civil Engineering Department assisted in carrying out part of the site monitoring works.

The report was reviewed by the undersigned as well as other members of the SCCT Subcommittee on AAR.

P L R Pang
Chief Geotechnical Engineer/Materials

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1. INTRODUCTION

In mid-1991, the Public Works Central Laboratory (PWCL) commenced a project to investigate the cause of extensive cracking of the concrete at the Shek Wu Hui Treatment Plant at the request of the Standing Committee on Concrete Technology (SCCT). An interim report on the investigation was issued in July 1992 (Wong & Koirala, 1992). This interim report suggests that the extensive cracking present in the concrete walls of the sedimentation and aeration tanks is likely to be due to alkali silica reaction (ASR).

As part of the project, cores taken from the structures were sent to SANDBERG in the UK for examination and testing. In November 1992, the Survey Division of the Civil Engineering Department (CED) was requested to carry out monitoring of the cracks using Demec gauges. Six crack locations were chosen and monitored. In December 1992, the PWCL installed Demec points at ten additional crack locations. The Demec points were installed in hexagonal rosettes to allow the expansions to be monitored in three directions.

This report summarises the additional work carried out between July 1992 and February 1994 and documents the results of the investigation.

2. INVESTIGATION BETWEEN JULY 1992 AND FEBRUARY 1994

2.1 Site Monitoring by the Survey Division of CED

The Survey Division of the CED carried out the following monitoring at the Shek Wu Hui Sewerage Treatment Plant :

(a) Stereo-photography and Crack Plotting

High definition stereo photographs were taken of an area with intensive cracks developed on the concrete surface. Precision plotting of the crack patterns to an accuracy of 1 mm was also produced (Figure 1). The data were stored in digital form in order that the development of any further cracking at that area could be monitored in future if required.

(b) Monitoring of Crack Movement

Pairs of Demec points were installed at 90 degrees to selected cracks. Six locations were chosen for carrying out such monitoring (viz. A1, P1, P3, P5, S2 and S4). A Demec gauge of 100 mm gauge length was used to monitor crack widening. Seven sets of triangular rosettes of three Demec points were also installed for the monitoring of crack widening and shearing dislocation (viz. A1-4, P1-5, P3-4, P5-7, P5-8, S2-4 and S4-4).

Since the installation of Demec points in December 1992, the cracks had been measured five times, with the last reading taken in February 1994. The results of the monitoring are given in Table 1. A graph showing a typical strain versus time curve derived from the monitoring results is shown in Figure 2.

2.2 Site Monitoring by the PWCL

Ten hexagonal rosettes of Demec points were installed to enable strains to be derived from the measurements in three directions (Figure 3 and Plate 1). A Demec gauge of 200 mm gauge length was used for the monitoring.

At each visit, measurements were taken four times in each of the three rosette directions. As two of these four measurements were aligned in a straight line, these readings were also combined to give a single measurement over a 400 mm gauge length.

Since the installation of Demec points in December 1992, the strains had been measured seven times. The ambient temperature and relative humidity were also recorded at the time of monitoring for reference purposes.

The strains measured in the horizontal, the left slanting and the right slanting directions were plotted against time for the ten selected monitoring locations. The results are shown in Figures 4 to 13. The ambient temperatures and relative humidities recorded are plotted against the dates of measurement in Figure 14.

2.3 Core Expansion Tests by the PWCL

Seventeen bars of 25 mm x 25 mm x 295 mm (approx.) long were prepared from nine 100 mm diameter cores taken from the selected locations at the walls of the sedimentation and aeration tanks at the Shek Wu Hui Sewage Treatment Plant.

Each core was first cut in half using the core-cutting machine. The half core was then further trimmed to two 25 mm x 25 mm bars. Stainless steel studs were installed to the ends of the bars following the steps given below:

(a) Wrap the bars in tin foils.
(b) Place each bar in a mould and fill the mould with plaster of Paris.
(c) Drill a 3 mm diameter hole to the centre of each end of the bar, enlarge the hole to 6 mm diameter by using a larger bit, and drill to a depth of about 17 mm.
(d) Fill the holes with zinc cement and insert the stainless steel studs.

The test procedure adopted is based on ASTM C227-87 (ASTM, 1987). The bars were individually wrapped in wet towels and placed inside a sealed plastic container. They were then stored in an environmental chamber with the temperature maintained at 38°C and relative humidity above 95%. The expansions of the bars were measured at regular intervals.

The test results indicate that after fourteen days all specimens showed an expansion of about 200 to 300 microstrains (equivalent to about 0.02 to 0.03%) but the subsequent expansion was negligible. The initial length and final length of the bars for the 17 test specimens are given in Table 2, together with the calculated strains. A graph showing the typical expansion for a period of 365 days is shown in Figure 15.

2.4 Petrographic Examination by the PWCL

The petrographic examination of concrete core samples was carried out generally in accordance with the requirements of ASTM C856-86 (ASTM, 1986). Reference was also made to the guidelines given in BCA (1992), French (1991) and West & Sibbick (1988).

Petrographic examination was undertaken on nine concrete core samples. Thin sections (except core SW107) and/or polished plates were made from each core sample. The thin sections and polished plates produced from core nos. SW102, SW107 (polished plate only), SW115, SW210 and SW213 were prepared and examined and those from cores SW203, SW206, SW208 and SW211 were sent to SANDBERG in the UK (see Section 2.5).

The thin sections were around 65mm long x 45mm wide x 30 μm thick and were vacuum impregnated with a fluorescent or colour dyed resin prior to preparation. They provided information on the cement/aggregate relationship, mineral phases in the cement and aggregate, aggregate composition, nature of microcracks and the identification and assessment of ASR reaction centres and gel products.

The polished plates were prepared from slices of core, 15-20 mm thick, taken along the core axis from the outer surface to depths 80-100 mm. They provided information on the aggregate size and type, the distribution and content of the voids, crack patterns and the form and distribution of ASR features.

A summary of the results of the petrographic examination, carried out on the nine concrete core samples, is given in Table 3.

2.5 Investigations by SANDBERG, UK

In March 1992, six concrete cores taken from the Shek Wu Hui Sewerage Treatment Plant were sent to SANDBERG in the UK for examination and testing. The investigation consisted of visual examination, petrographic examination, crack pattern analysis and core expansion tests. The main objective of the investigation is to identify whether there is evidence of ASR occurring in these cores.

The petrographic examination has identified unequivocal, although non-abundant signs of ASR, and study of the micro-crack patterns of the cores and their relationship to the reaction sites within the cores confirms a probable association.

The core expansion tests have indicated ASR to be dormant, with little residual potential for continued expansive behaviour.

Further details of the investigation are given in the report by SANDBERG (1993) and are not repeated here.

3. DISCUSSION OF RESULTS

The site monitoring works carried out by the Survey Division and the PWCL of CED both indicate that the concrete structures at the Shek Wu Hui Treatment Plant have no signs of continued expansion. This is consistent with the results of SANDBERG's investigation which indicates that the ASR in the concrete cores is dormant.

The concrete core expansion test can be used to assess the potential for continued expansion. BCA (1992) suggests that if the total observed expansion is about 700 microstrains or less in the expansion tests, it is unlikely that there will be further expansion of the member from which the cores were taken. The PWCL expansion test results show that the total expansion is about 200 to 300 microstrains for all of the 17 test specimens. The expansion in the early stage of the test may be attributed to the additional water absorption by the existing ASR gel. It may also be due to thermal expansion associated with raising the temperature of the cores to 38°C. Negligible expansion was then recorded in the later stage of the tests. This lends further support that ASR in the concrete structures has come to an end.

It is of interest to note that the strains derived from field monitoring and strains obtained from core expansion tests are of similar magnitude. However, it is not possible to determine what proportion of strain measured from field monitoring is due to ASR. With hindsight, field monitoring could have included locations which are free of ASR cracking. This would have enabled the strain component due to ASR to be separated from strains due to other causes.

Good correlation is obtained between the results of the petrographic examinations carried out by the PWCL and by SANDBERG. The cores examined generally exhibited similar composition consisting of volcanic tuff coarse aggregate, fine aggregate of predominantly granite and volcanic tuff, and Ordinary Portland Cement with no additives.

The coarse and fine volcanic tuff aggregate contains abundant microcrystalline quartz in the rock matrix and strained quartz in the coarse crystal component which are widely recognised as potentially reactive materials (RILEM, 1993).

Evidence of ASR was observed in all of the core samples examined except SW115. The evidence included the presence of reaction sites and residual gel deposits in voids and microcracks. The extent of the reaction was generally quite limited in most of the core samples except SW102 and SW206, which contained numerous reaction sites and abundant gel deposits. The reaction sites where observed were mainly associated with coarse aggregate particles.

The gel deposits observed in voids and microcracks were frequently carbonated and recrystallised suggesting that much of the reaction may be historical.

The presence of potentially reactive aggregate particles together with evidence of reaction sites and the occurrence of alkali silica gel identified in the core samples examined is considered to represent confirmation that ASR has occurred in the concrete (BCA, 1992; West & Sibbick, 1988).

4. CONCLUSIONS AND RECOMMENDATIONS

This is the first documented case study on ASR performed by the PWCL. Through this study, the PWCL has developed testing capabilities to enable ASR in concrete to be identified and confirmed.

Petrographic examination has confirmed the presence of ASR in the majority of the cores examined. However, petrographic examination on its own is not able to provide information on the extent or rate of deterioration of the concrete resulting from ASR. It should be carried out in conjunction with field monitoring over a period of time (BCA, 1992).

The insitu monitoring of cracks carried out at the Shek Wu Hui Treatment Plant by the Survey Division and the PWCL of CED indicates negligible movement throughout the monitoring period which is about one and a half years.

The core expansion tests carried out by the PWCL indicate that there is unlikely to be any further expansion in the structures from which the cores have been taken.

The investigation carried out by SANDBERG on the cores taken from the site confirms that the cracks in the concrete structures were due to the presence of ASR. SANDBERG'S finding also confirms that the ASR is dormant and further cracking of the structures is unlikely to occur.

Despite the relatively low risk of further deterioration of the structures due to ASR, there is potential for deterioration due to other forms of attack (e.g. corrosion of steel reinforcement due to chloride) given the extensive cracking that has occurred. It is recommended that consideration be given to examining the need for protection and repair of the structures.

It is also recommended that further work be carried out to establish appropriate test methods and procedures for determining the potential reactivity of concrete constituent materials used in Hong Kong.

5. REFERENCES

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Table 1 – Strains Calculated from Demec Gauge Measurements Obtained by the Survey Division of CED

Point	Line	02-Dec-92 (Initial)	16-Dec-92	04-Jan-93	02-Feb-93	25-Aug-93	03-Feb-94 (Final)	Diff. in Reading (2)	Strain x 10^-6 (2)
A1-1		875	876	877	881	919	897	16	259
A1-2		1241	1296	1268	1307	1363	1587	-- (1)	--
A1-3		1556	1559	1569	1582	1604	1600	18	292
A1-4	1--2	976	962	968	969	998	1013	44	713
	2--3	1341	1342	1344	1345	1360	1360	15	243
	3--1	1718	1714	1717	1728	1744	1758	30	486
P1-1		1850	1858	1855	1857	1860	1872	15	243
P1-2		1843	1909	1837	1852	1835	1888	36	583
P1-3		946	945	941	944	950	960	16	259
P1-4		494	483	482	490	493	506	16	259
P1-5	1--2	1867	1872	1869	1872	1875	1880	8	130
	2--3	1418	1428	1427	1430	1441	1427	-3	-49
	3--1	466	470	469	474	474	482	8	130
P3-1		1864	1865	1869	1876	1886	1888	12	194
P3-2		1878	1882	1885	1886	1896	1907	21	340
P3-3		394	396	406	406	416	426	20	324
P3-4	1--2	1957	1954	1947	1943	1970	1967	24	389
	2--3	2384	2382	2377	2381	2388	2372	-9	-146
	3--1	2306	2300	2303	2304	2309	2307	3	49
P5-1		1132	1128	1133	1142	1155	1190	48	778
P5-2		2081	2076	2076	2075	2084	2100	25	405
P5-3		1486	1488	1478	1487	1506	1521	34	551
P5-4		1686	1685	1694	1692	1704	1711	19	308
P5-5		624	624	630	633	642	644	11	178
P5-6		607	614	610	610	626	632	22	356
P5-7	1--2	533	546	544	545	554	558	13	211
	2--3	1356	1364	1374	1378	1380	1377	-1	-16
	3--1	1235	1243	1253	1252	1254	1262	10	162
P5-8	1--2	2009	2004	2002	2002	2015	2027	25	405
	2--3	1122	1124	1135	1126	1140	1137	11	178
	3--1	849	848	846	845	857	865	20	324
S2-1		2129	2131	2136	2139	2150	2161	22	356
S2-2		1590	1595	1603	1604	1612	1604	0	0
S2-3		1636	1632	1634	1640	1654	1651	11	178
S2-4	1--2	1108	1108	1107	1109	1116	1122	13	211
	2--3	2268	2267	2274	2279	2284	2279	0	0
	3--1	1940	1938	1937	1938	1956	1953	15	243
S4-1		1804	1812	1807	1810	1820	1832	22	356
S4-2		1093	1104	1095	1095	1106	1131	36	583
S4-3		191	200	197	200	206	223	23	373
S4-4	1--2	1566	1558	1549	1566	1587	1579	13	211
	2--3	1978	1975	1987	1992	1998	1967	-25	-405
	3--1	1772	1768	1766	1773	1787	1793	20	324

Notes :

(1) Measurement was obstructed by cable, result discarded.

(2) Strain was calculated by multiplying the difference in readings between 02.02.93 and 03.02.94 by a factor C = 0.0000162.

Table 2 - Core Expansion Test Results

Date Started : 01/06/92
Date Ended : 03/06/93
Age : 367 days
Temperature : 38°C
R.H. : 95%

Specimen No.	Initial Length (mm)	Final Length (mm)	Strain x 10^{-6}
SW101B	292.529	292.610	324
SW104A	292.342	292.401	236
SW104B	291.888	291.945	228
SW112A	297.111	297.183	288
SW112B	296.741	296.814	292
SW113A	291.577	291.629	208
SW113B	291.123	291.184	244
SW114A	295.445	295.498	212
SW114B	295.321	295.375	216
SW116A	297.718	297.765	188
SW116B	294.602	294.647	180
SW117A	294.663	294.739	304
SW117B	295.636	295.707	284
SW118A	296.567	296.625	232
SW118B	295.428	295.488	240
SW120A	295.243	295.290	188
SW120B	297.101	297.159	232

Table 3 - Summary of Petrographic Examination Results on Concrete Cores

Core/Specimen No.	Cement	Coarse Aggregate	Fine Aggregate	Cracking	Presence of Reactive Minerals	Presence of Gel
SW102/1 (THIN SECTION) SW102/2 (POLISHED PLATE)	SURFACE CARBONATION TO 5-10 mm (15-20 mm IN SURFACE CRACKS) RESIDUAL CLINKER FINELY DIVIDED AND GENERALLY <10 μm SIZE, OCCASIONALLY UP TO 100 μm. PORTLANDITE WHERE DEVELOPED GENERALLY <10 μm - 50 μm. SMALL NUMBER OF VOIDS <1 mm ON AVERAGE SIZE, OCCASIONALLY UP TO 5 mm.	20 mm NOMINAL SIZE CRUSHED ROCK. PREDOMINANTLY FINE GRAINED VOLCANIC TUFF. SOME FLAKY AND ELONGATE PARTICLES.	5 mm NOMINAL SIZE CRUSHED ROCK. PREDOMINATELY FINE GRAINED SLIGHTLY WEATHERED GRANITE WITH OCCASIONAL VOLCANIC TUFF, MICA SCHIST AND SOME FREE QUARTZ, FELDSPAR AND MICA.	SURFACE MACROCRACKS PENETRATE TO SEVERAL cm DEPTH. SOME MINOR MICROCRACKS IN CEMENT BETWEEN AGGREGATE PARTICLES.	MICROCRYSTALLINE AND STRAINED QUARTZ PRESENT IN COARSE AND SOME FINE AGGREGATE PARTICLES. REACTION RIMS AROUND MANY OF THE COARSE AND FINE VOLCANIC AGGREGATE PARTICLES.	CONSIDERABLE GEL EXUDATION IN POLISHED PLATE AROUND COARSE AGGREGATE PARTICLES. TRACE OF LAYERED AND RESIDUAL GEL IN MICROCRACKS IN THIN SECTION.
SW107/1 (POLISHED PLATE)	SURFACE CARBONATION TO 2-3 mm DEPTH WITH PATCHY CARBONATION, THROUGHTOUT SAMPLE. NUMEROUS VOIDS UP TO SEVERAL mm DIAMETER AND DEPTH.	20 mm NOMINAL SIZE CRUSHED ROCK. PREDOMINANTLY FINE GRAINED VOLCANIC TUFF WITH OCCASIONAL FREE QUARTZ PARTICLES.	5 mm NOMINAL SIZE CRUSHED ROCK. MIXED SOURCES OF GRANITE, TUFF AND SOME FREE QUARTZ.	SINGLE MACROCRACK PENETRATING FROM OUTER SURFACE OF CORE TO AROUND 30 mm DEPTH. OCCASIONAL MICROCRACKS IN COARSE AGGREGATE PARTICLES PARTLY LINED WITH RESIDUAL GEL.	OCCASIONAL REACTION RIMS AROUND COARSE AGGREGATE PARTICLES.	TRACES OF RESIDUAL GEL IN SOME REACTION RIMS AROUND COARSE AGGREGATE PARTICLES.

Table 3 - Summary of Petrographic Examination Results on Concrete Cores (Cont.)

Core/Specimen No.	Cement	Coarse Aggregate	Fine Aggregate	Cracking	Presence of Reactive Minerals	Presence of Gel
SW115/1 (THIN SECTION) SW115/2 (POLISHED PLATE)	SURFACE CARBONATION TO 2-3 mm. PATCHY CARBONATION THROUGHOUT CORE ADJACENT TO VOIDS AND COARSE AGGREGATE PARTICLES. RESIDUAL CLINKER FINELY DIVIDED AND GENERALLY <10 μm, OCCASIONALLY UP TO 200 μm. PORTLANDITE WHERE DEVELOPED GENERALLY UP TO 50 μm IN SIZE. NUMEROUS VOIDS THROUGHOUT CORE, BETWEEN 0.5 mm - 2 mm, OCCASIONALLY UP TO 5 mm.	20 mm NOMINAL SIZE CRUSHED ROCK. PREDOMINANTLY FINE GRAINED VOLCANIC TUFF. OCCASIONAL FREE QUARTZ PARTICLES. SOME FLAKY AND ELONGATE PARTICLES.	5 mm NOMINAL SIZE CRUSHED ROCK PREDOMINANTLY SAME AS COARSE AGGREGATE WITH SOME PARTICLES OF MICA SCHIST, CALCITE AND FREE MICA.	OCCASIONAL MICROCRACKS PRESENT IN THE CEMENT.	MICROCRYSTALLINE AND STRAINED QUARTZ PRESENT IN COARSE AND FINE AGGREGATE. OCCASIONAL REACTION RIMS IN COARSE AGGREGATE PARTICLES OBSERVED IN POLISHED PLATE.	TRACK OF RESIDUAL GEL IN MICROCRACKS IN POLISHED PLATE.
SW203/1 (THIN SECTION) SW203/2 (POLISHED PLATE)	SURFACE CARBONATION TO 3-4 mm (UP TO 73 mm IN CRACKS). ABUNDANT RESIDUAL CLINKER UP TO 140 μm IN SIZE. SPORADIC TO FREQUENT DEVELOPMENT OF PORTLANDITE CRYSTALS UP TO 30 μm. SMALL NUMBER OF VOIDS UP TO 2.5 mm IN DIAMETER. ETTRINGITE CRYSTALS PRESENT IN MANY OF THE VOIDS.	20 mm NOMINAL SIZE CRUSHED ROCK. PREDOMINANTLY FINE GRAINED VOLCANIC TUFF.	5 mm NOMINAL SIZE CRUSHED ROCK. PREDOMINANTLY FINE GRAINED GRANITE WITH SOME FREE QUARTZ, FELDSPAR AND MICA.	SURFACE MACROCRACKS PENETRATING TO SEVERAL cm DEPTH. FREQUENT MICROCRACKS IN CEMENT AND AROUND AGGREGATE PARTICLES. ETTRINGITE PRESENT IN SOME CRACKS.	MICROCRYSTALLINE QUARTZ PRESENT IN COARSE AGGREGATE.	MINOR DEPOSITS OF RESIDUAL GEL IN CRACKS.

Table 3 - Summary of Petrographic Examination Results on Concrete Cores (Cont.)

Core/Specimen No.	Cement	Coarse Aggregate	Fine Aggregate	Cracking	Presence of Reactive Minerals	Presence of Gel
SW206/1 (THIN SECTION) SW206/2 (POLISHED PLATE)	SURFACE CARBONATION TO 1-3 mm (UP TO 25 mm IN CRACKS). ABUNDANT RESIDUAL CLINKER UP TO 200 μm IN SIZE.FREQUENT DEVELOPMENT OF PORTLANDITE CRYSTALS UP TO 30 μm. SMALL NUMBER OF VOIDS UP TO 2mm IN DIAMETER. ETTRINGITE CRYSTALS FREQUENTLY PRESENT IN SMALL VOIDS.	20 mm NOMINAL SIZE CRUSHED ROCK. PREDOMINANTLY FINE GRAINED VOLCANIC TUFF.	5 mm NOMINAL SIZE CRUSHED ROCK. PREDOMINATELY FINE GRAINED GRANITE WITH SOME FREE QUARTZ, FELDSPAR AND MICA.	NUMEROUS MACROCRACKS AND MICROCRACKS THROUGHOUT CORE SPECIMEN PASSING THROUGH BOTH CEMENT AND AGGREGATE PARTICLES. ETTRINGITE PRESENT IN SOME CRACKS.	MICROCRYSTALLINE QUARTZ PRESENT IN COARSE AGGREGATE. REACTION TAKING PLACE AROUND MANY OF THE COARSE AGGREGATE PARTICLES.	GEL FILLING SOME VOIDS UP TO 2 mm IN SIZE AND FREQUENTLY VISIBLE WITHIN CRACKS ASSOCIATED WITH REACTING COARSE AGGREGATE PARTICLES.
SW208/1 (THIN SECTION) SW208/2 (POLISHED PLATE)	SURFACE CARBONATION TO 5-10 mm (UP TO 22 mm IN CRACKS). ABUNDANT RESIDUAL CLINKER UP TO 160 μm IN SIZE. FREQUENT DEVELOPMENT OF PORTLANDITE CRYSTALS UP TO 40 μm. SMALL NUMBER OF VOIDS UP TO 3 mm IN DIAMETER. ETTRINGITE CRYSTALS FREQUENTLY PRESENT IN VOIDS.	20 mm NOMINAL SIZE CRUSHED ROCK. PREDOMINANTLY FINE GRAINED VOLCANIC TUFF.	5 mm NOMINAL SIZE. CRUSHED ROCK. PREDOMINANTLY FINE GRAINED GRANITE WITH SOME FREE QUARTZ, FELDSPAR AND MICA.	NUMEROUS MACROCRACKS AND MICROCRACKS PASSING THROUGH BOTH CEMENT AND AGGREGATE PARTICLES. ETTRINGITE PRESENT IN SOME CRACKS.	MICROCRYSTALLINE QUARTZ PRESENT IN COARSE AGGREGATE. REACTION TAKING PLACE AROUND MANY OF THE COARSE AGGREGATE PARTICLES.	GEL FILLING SOME CRACKS AND SMALL VOIDS OFTEN ASSOCIATED WITH REACTING COARSE AGGREGATE PARTICLES.

Table 3 - Summary of Petrographic Examination Results on Concrete Cores (Cont.)

Core/Specimen No.	Cement	Coarse Aggregate	Fine Aggregate	Cracking	Presence of Reactive Minerals	Presence of Gel
SW210/1 SW210/2 (THIN SECTIONS) SW210/3 (POLISHED PLATE)	SURFACE CARBONATION TO 5 mm (10-15 mm IN CRACKS). RESIDUAL CLINKER FINELY DIVIDED AND GENERALLY <50 µm, OCCASIONALLY UP TO 200-300 µm IN SIZE. PORTLANDITE CRYSTALS WHERE DEVELOPED ARE AROUND 50 µm, OCCASIONALLY 100 µm IN SIZE. SMALL NUMBER OF VOIDS GENERALLY <2 mm IN SIZE. VOIDS OCCASIONALLY LINED WITH ETTRINGITE CRYSTALS.	20 mm NOMINAL SIZE CRUSHED ROCK. PREDOMINANTLY FINE GRAINED VOLCANIC ROCK (MAINLY TUFF WITH OCCASIONAL BASALT) WITH OCCASIONAL FREE QUARTZ PARTICLES. SOME FLAKY AND ELONGATE PARTICLES.	5 mm NOMINAL SIZE. PREDOMINANTLY SAME AS COARSE AGGREGATE WITH SOME PARTICLES OF QUARTZ AND MICA.	SURFACE MACROCRACKS PENETRATE TO SEVERAL cm DEPTH. SOME FINE CRACKS AND MICROCRACKS PASSING THROUGH CEMENT AND AGGREGATE PARTICLES.	MICROCRYSTALLINE AND STRAINED QUARTZ PRESENT IN COARSE AND FINE AGGREGATE. SOME REACTION CENTRES PRESENT MAINLY IN COARSE AGGREGATE WITH OCCASIONAL REACTION RIMS.	TRACES OF RESIDUAL AND LAYERED GEL IN SOME MICROCRACKS AND WITHIN REACTION RIMS AROUND AGGREGATE PARTICLES AND OCCASIONALLY IN SMALL VOIDS.
SW211/1 (THIN SECTION) SW211/2 (POLISHED PLATE)	SURFACE CARBONATION VARIABLE BETWEEN 0.5 mm TO 5 mm DEEP (UP TO 36 mm IN CRACKS). ABUNDANT RESIDUAL CLINKER UP TO 130 µm IN SIZE. PORTLANDITE CRYSTALS WHERE DEVELOPED ARE AROUND 50 µm IN SIZE. SMALL NUMBER OF VOIDS UP TO 4.5 mm DIAMETER. ETTRINGITE CRYSTALS FREQUENTLY PRESENT IN VOIDS.	20 mm NOMINAL SIZE CRUSHED ROCK. PREDOMINANTLY FINE. GRAINED VOLCANIC TUFF.	5 mm NOMINAL SIZE CRUSHED ROCK. PREDOMINANTLY FINE GRAINED GRANITE WITH SOME FREE QUARTZ, FELDSPAR AND MICA.	SEVERAL MACROCRACKS AND MICROCRACKS. PASSING THROUGH BOTH CEMENT AND AGGREGATE PARTICLES. ETTRINGITE PRESENT IN SOME MICROCRACKS.	MICROCRYSTALLINE QUARTZ PRESENT IN COARSE AGGREGATE.	TRACES OF RESIDUAL GEL IN SOME MICROCRACKS.

Table 3 - Summary of Petrographic Examination Results on Concrete Cores

Core/Specimen No.	Cement	Coarse Aggregate	Fine Aggregate	Cracking	Presence of Reactive Minerals	Presence of Gel
SW213/1 (THIN SECTION) SW213/2 (POLISHED PLATE)	SURFACE CARBONATION TO 2 TO 5 mm, SLIGHT CARBONATION AROUND VOIDS. RESIDUAL CLINKER FINELY DIVIDED AND GENERALLY BETWEEN 10 to 50 µm, OCCASIONALLY UP TO 200 µm SIZE. PORTLANDITE CRYSTALS WHERE DEVELOPED ARE GENERALLY AROUND 50 µm IN SIZE. SMALL NUMBER OF VOIDS GENERALLY 250 to 300 µm IN SIZE OCCASIONALLY UP TO 3 mm. ETTRINGITE CRYSTALS FREQUENTLY PRESENT IN VOIDS.	20 mm NOMINAL SIZE CRUSHED ROCK. PREDOMINANTLY FINE GRAINED VOLCANIC TUFF WITH OCCASIONAL QUARTZ MICA SCHIST. SOME FLAKY AND ELONGATE PARTICLES.	5 mm NOMINAL SIZE CRUSHED ROCK PREDOMINANTLY SAME AS COARSE AGGREGATE WITH SOME FREE QUARTZ AND MICA.	SURFACE MACROCRACKS PENETRATE TO SEVERAL cm DEPTH. MINOR MICROCRACKS IN CEMENT BETWEEN AGGREGATE PARTICLES.	MICROCRYSTALLINE AND STRAINED QUARTZ PRESENT IN COARSE AND FINE AGGREGATE. NO EVIDENCE OF REACTION CENTRES.	NONE

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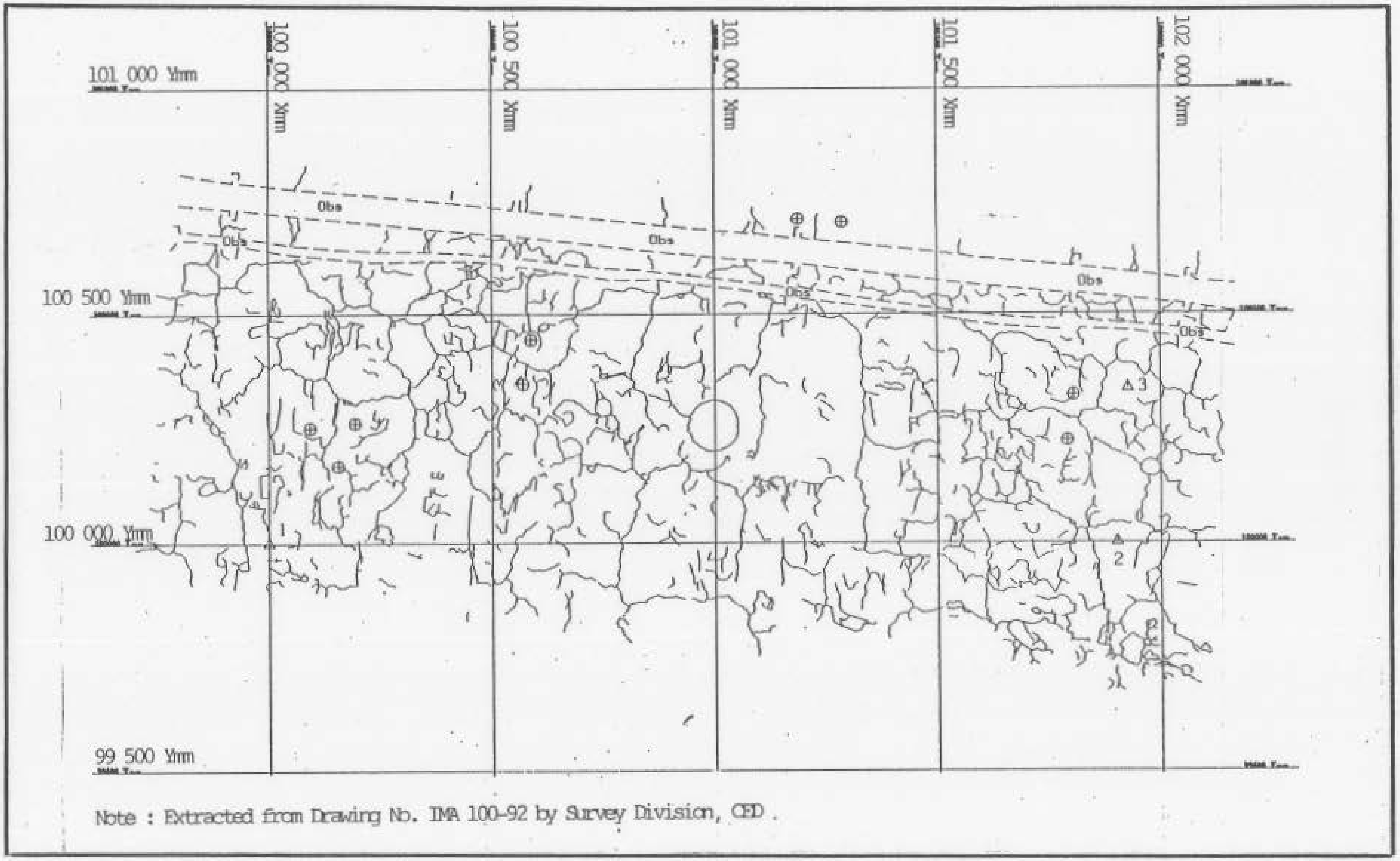

Note : Extracted from Drawing No. IMA 100-92 by Survey Division, CED .

Figure 1 - Precision Plotting of Cracks by Survey Division, CED

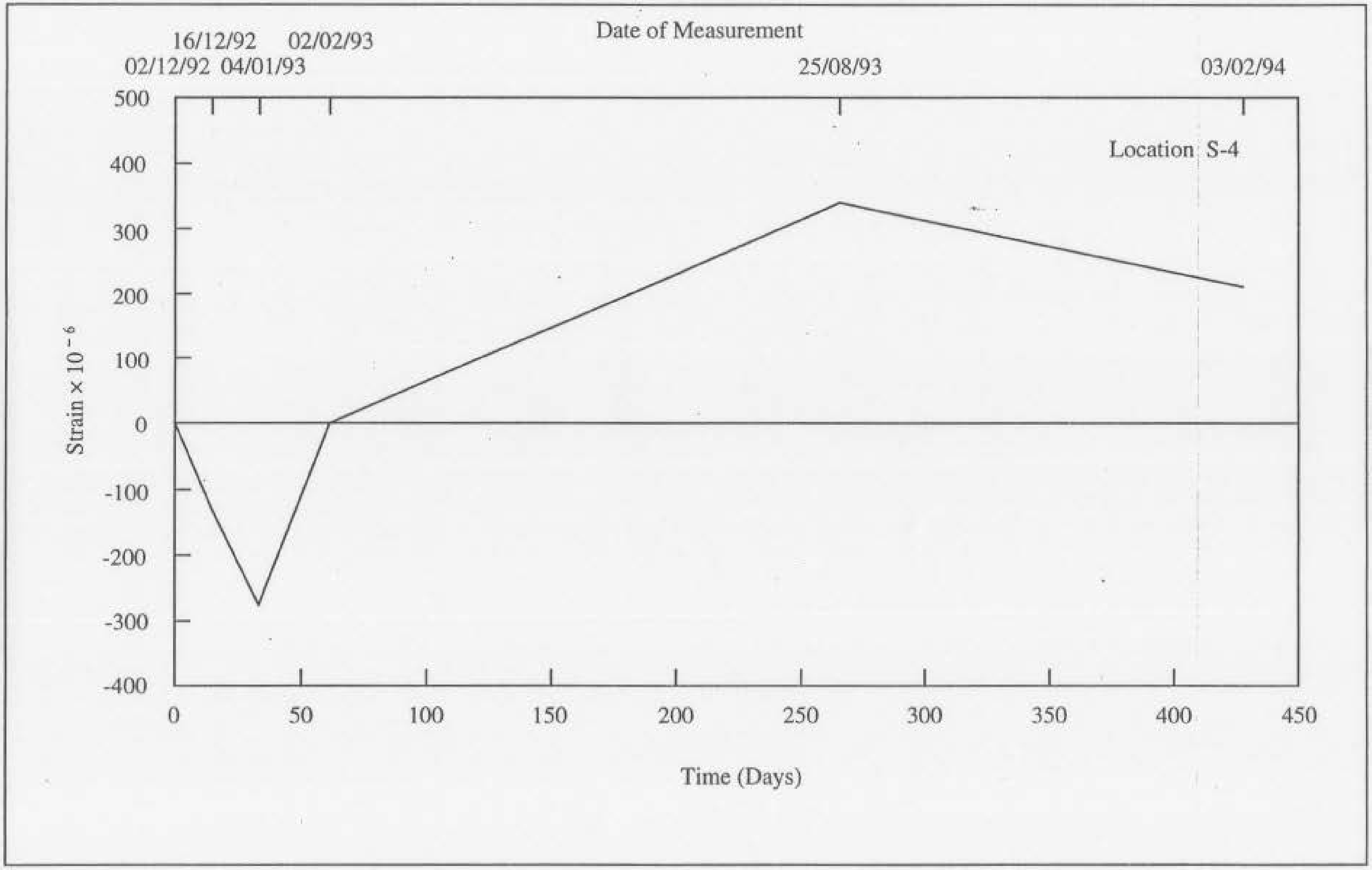

Figure 2 - Typical Graph for Strain Measurement at Crack Location S-4 by Survey Division, CED

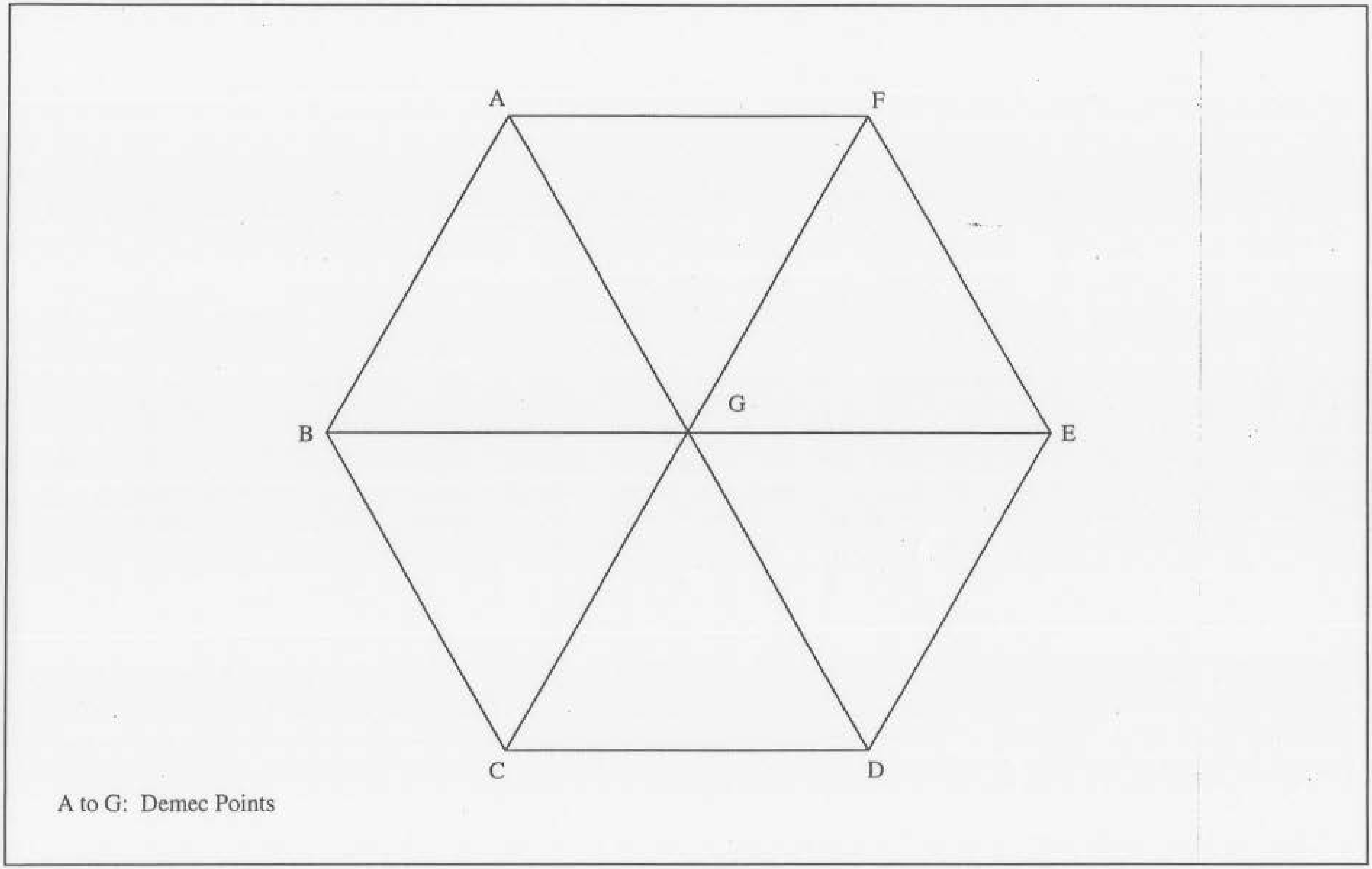

Figure 3 - Rosette Positions of Demec Points Installed at Selected Locations for Insitu Monitoring of Cracks by the PWCL

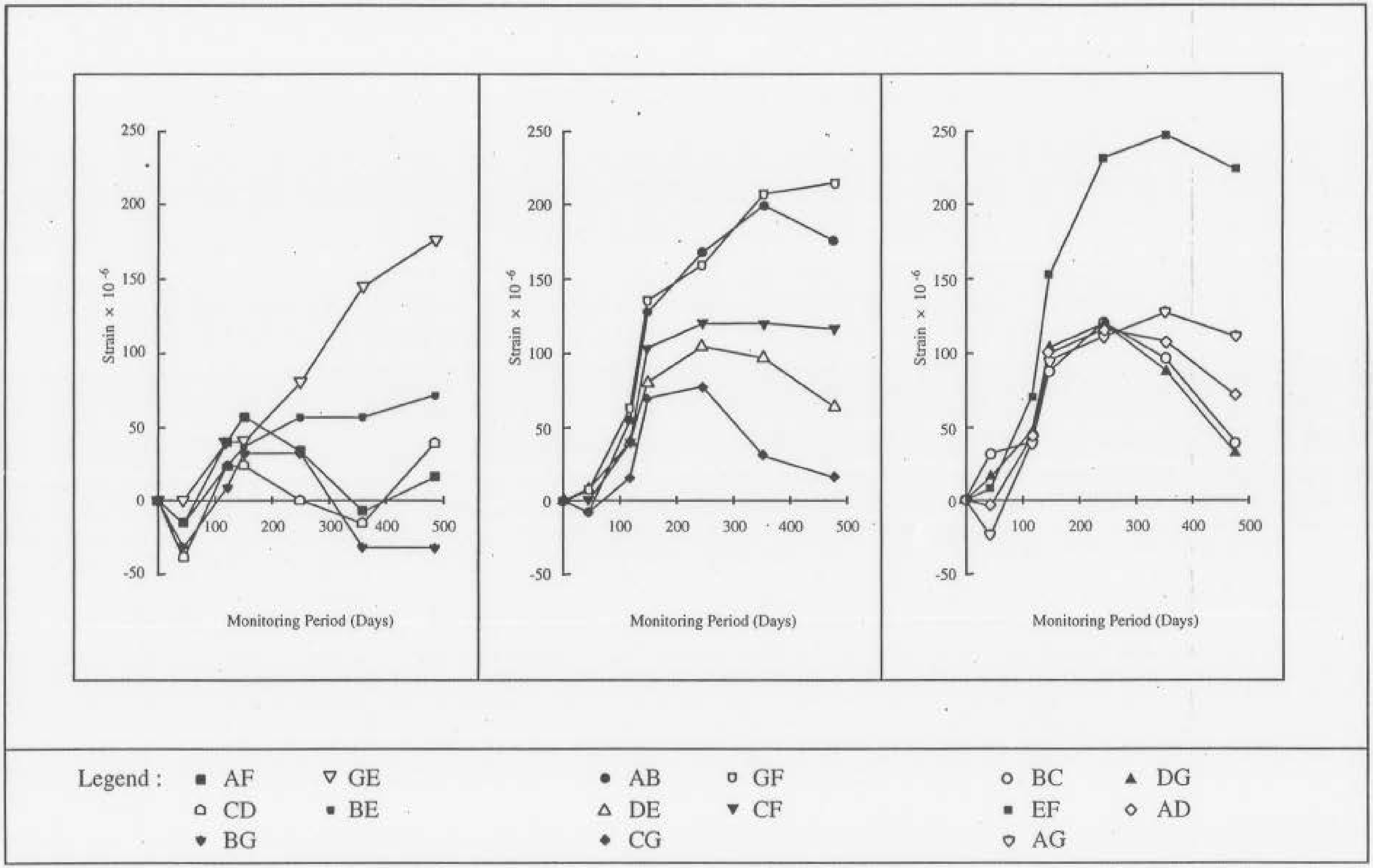

Figure 4 - Results of Insitu Measurement of Cracks by the PWCL for Panel A

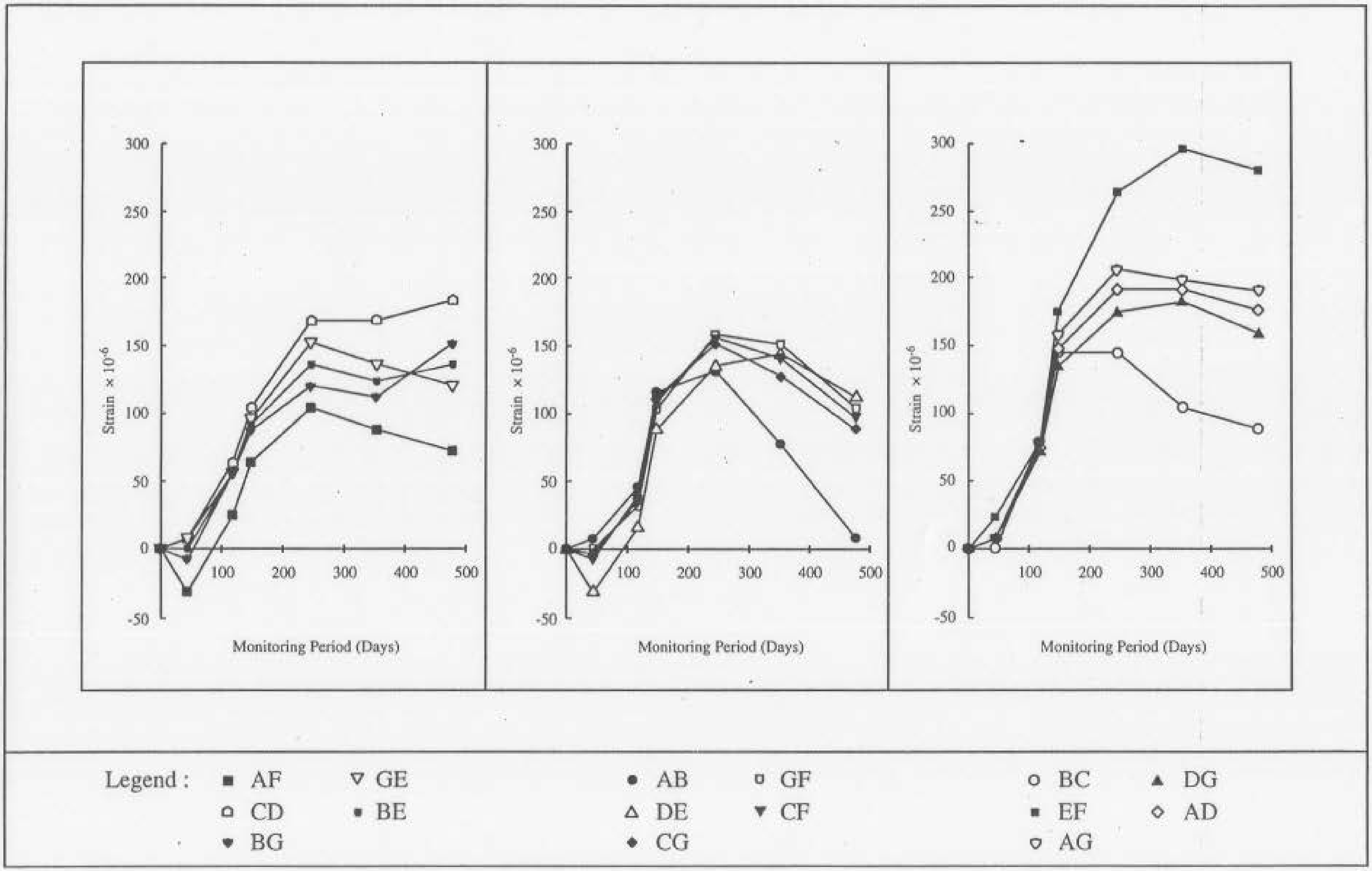

Figure 5 - Results of Insitu Measurement of Cracks by the PWCL for Panel B

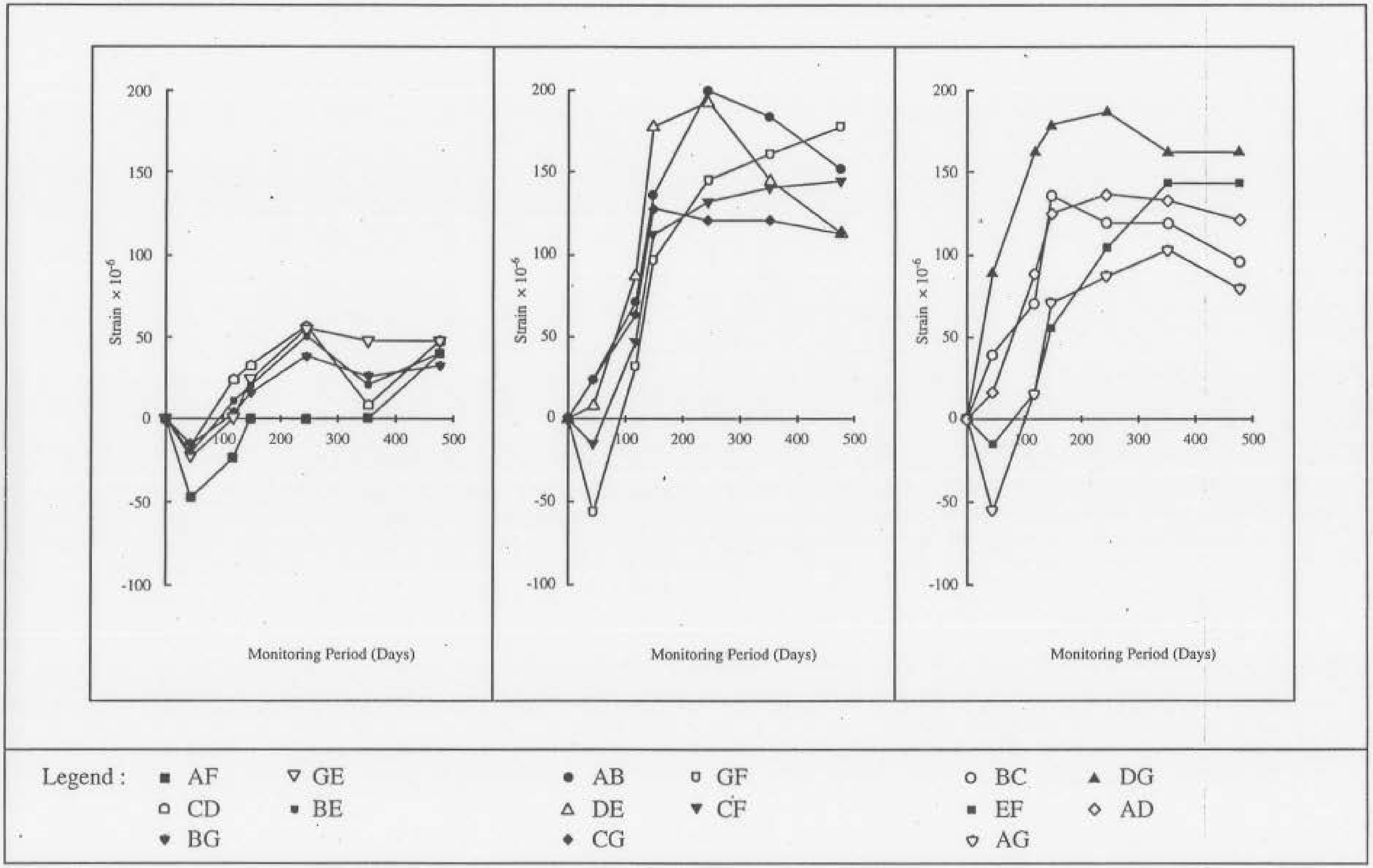

Figure 6 - Results of Insitu Measurement of Cracks by the PWCL for Panel C

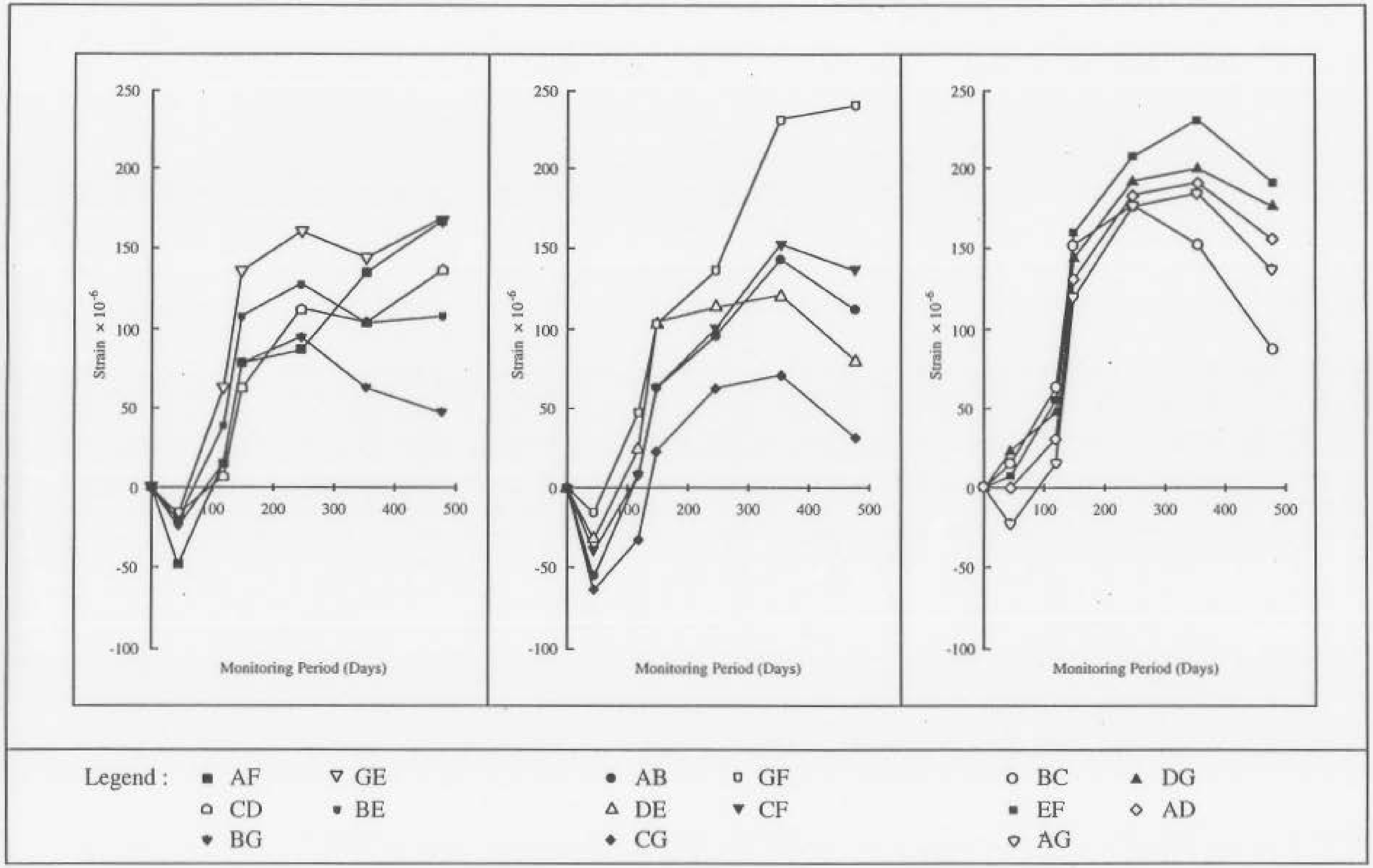

Figure 7 - Results of Insitu Measurement of Cracks by the PWCL for Panel D

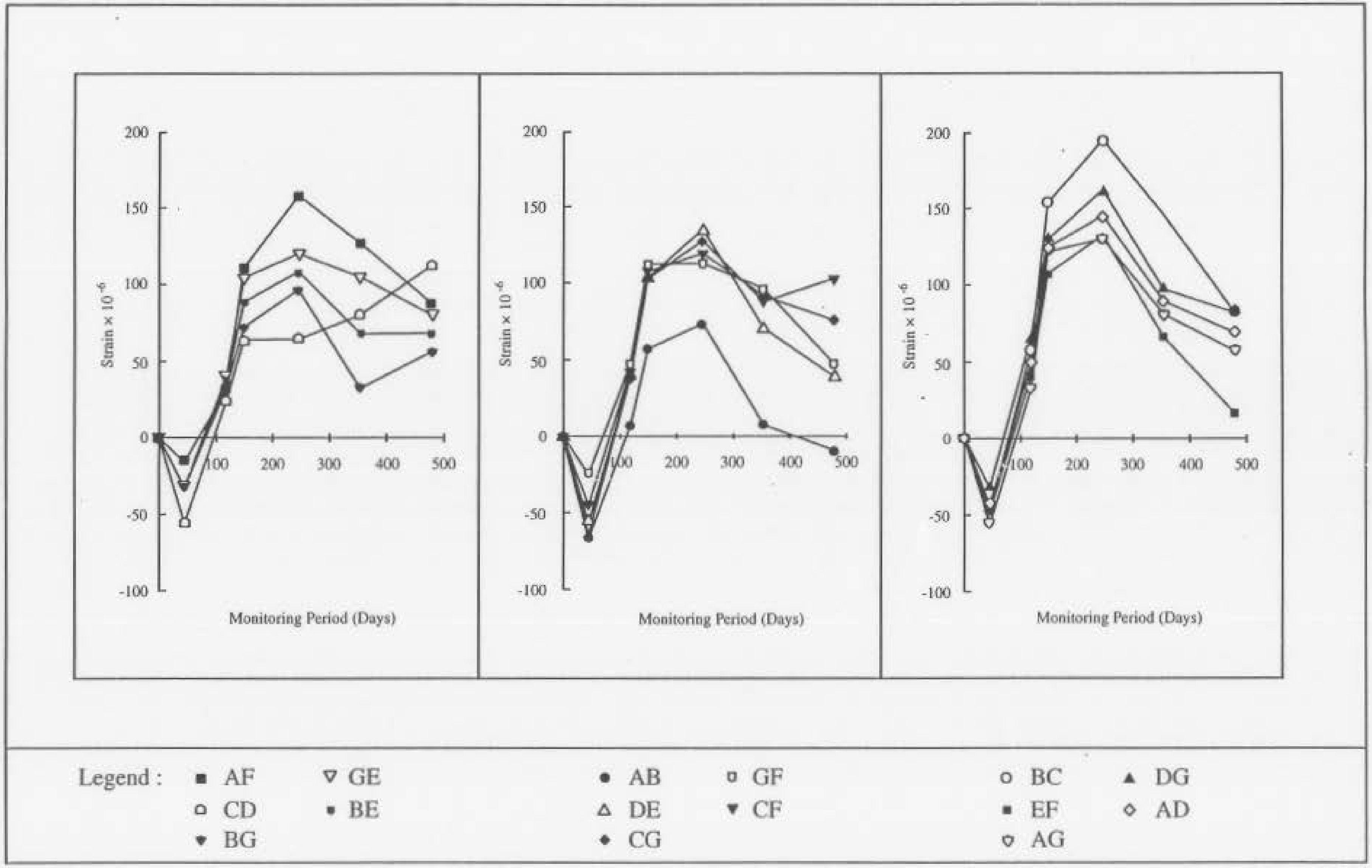

Figure 8 - Results of Insitu Measurement of Cracks by the PWCL for Panel E1

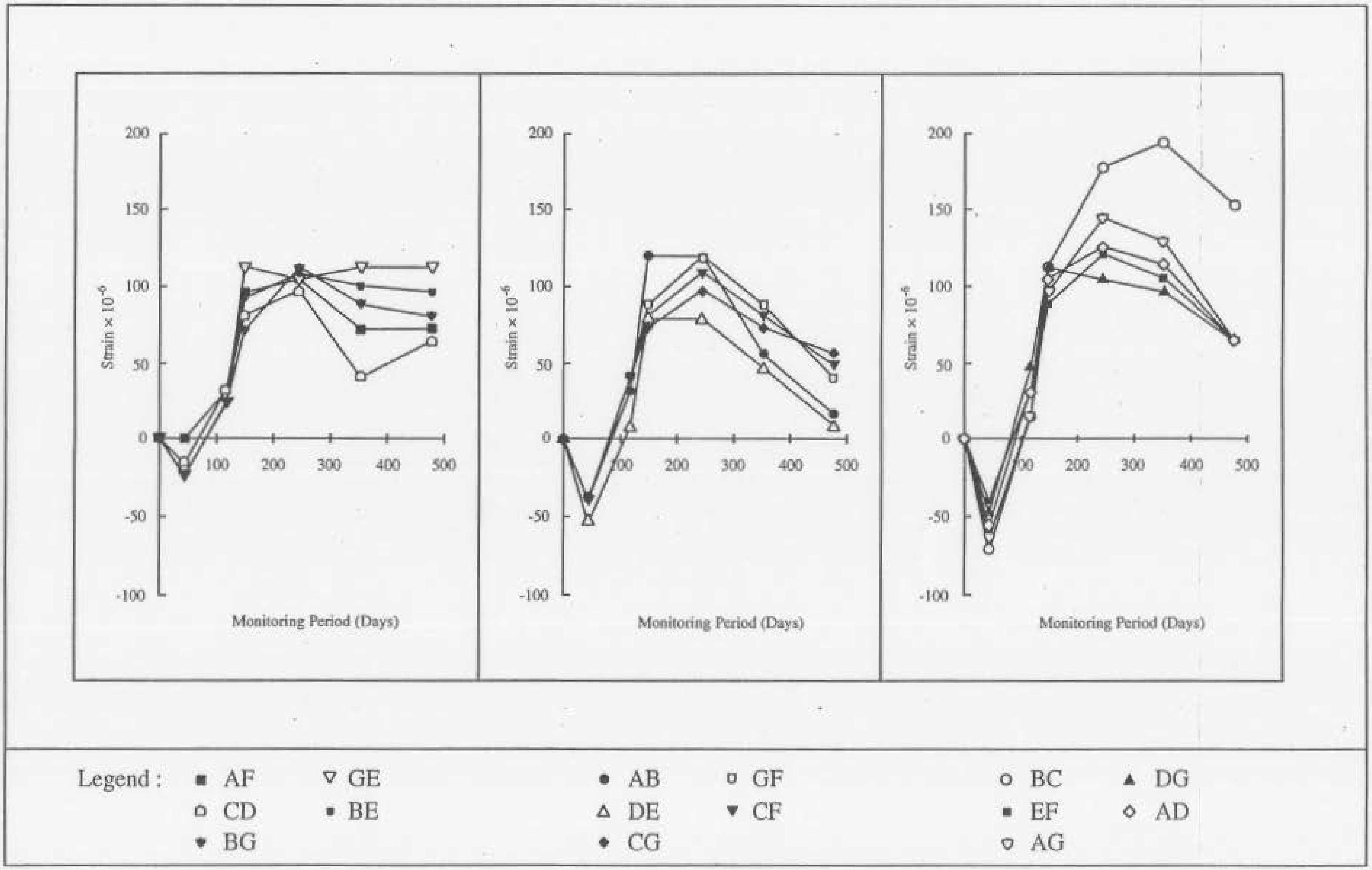

Figure 9 - Results of Insitu Measurement of Cracks by the PWCL for Panel E2

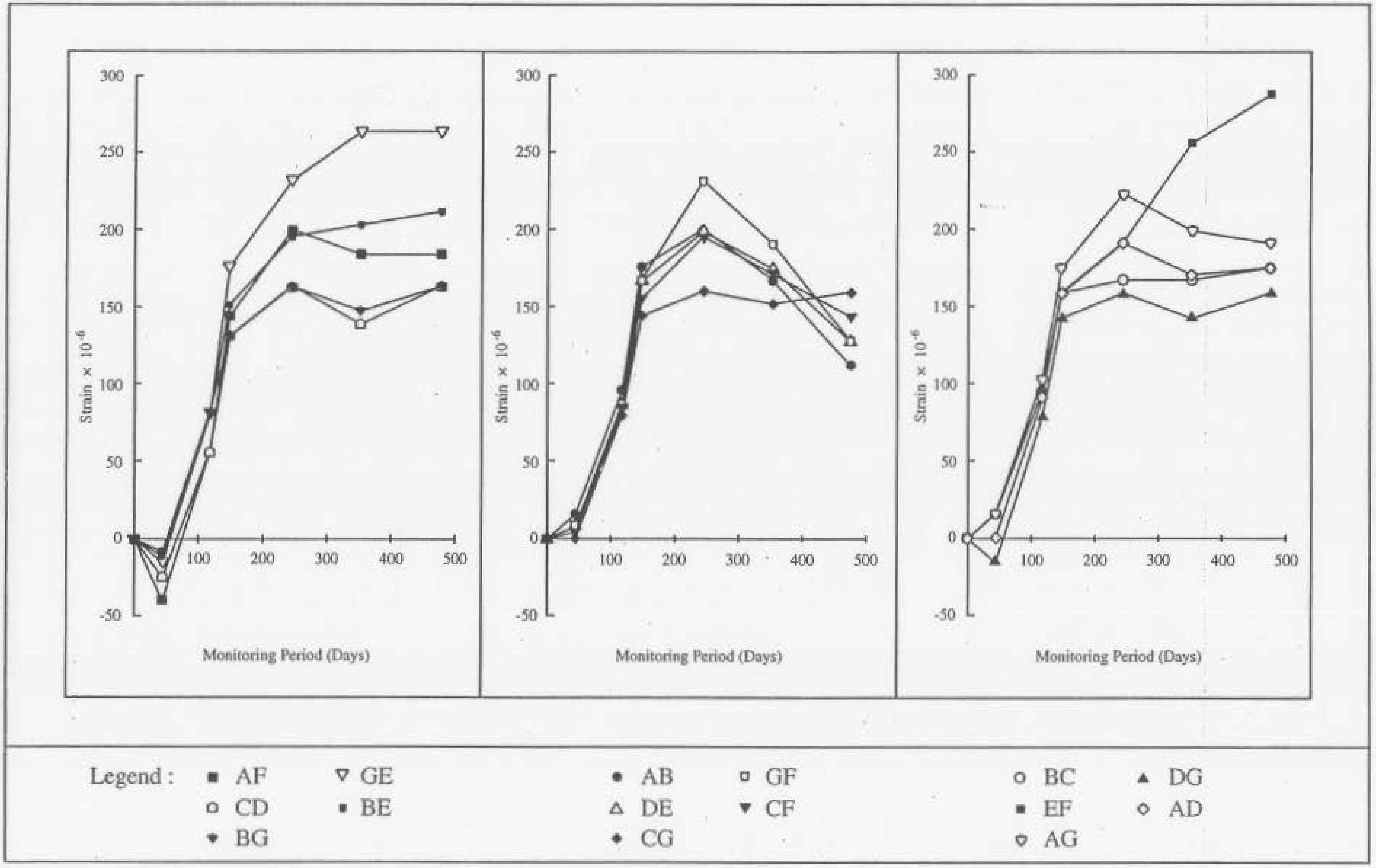

Figure 10 - Results of Insitu Measurement of Cracks by the PWCL for Panel F

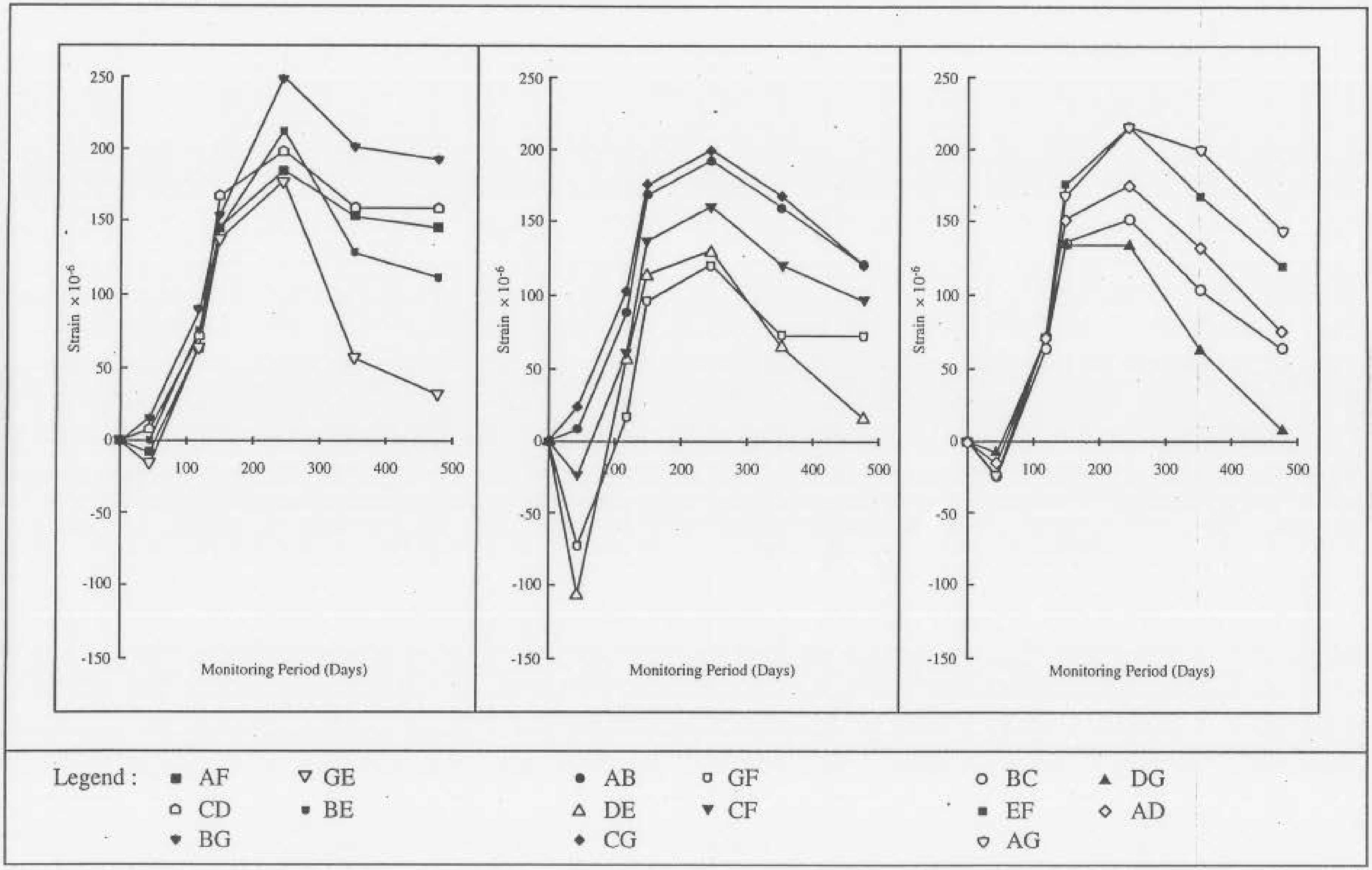

Figure 11 - Results of Insitu Measurement of Cracks by the PWCL for Panel G

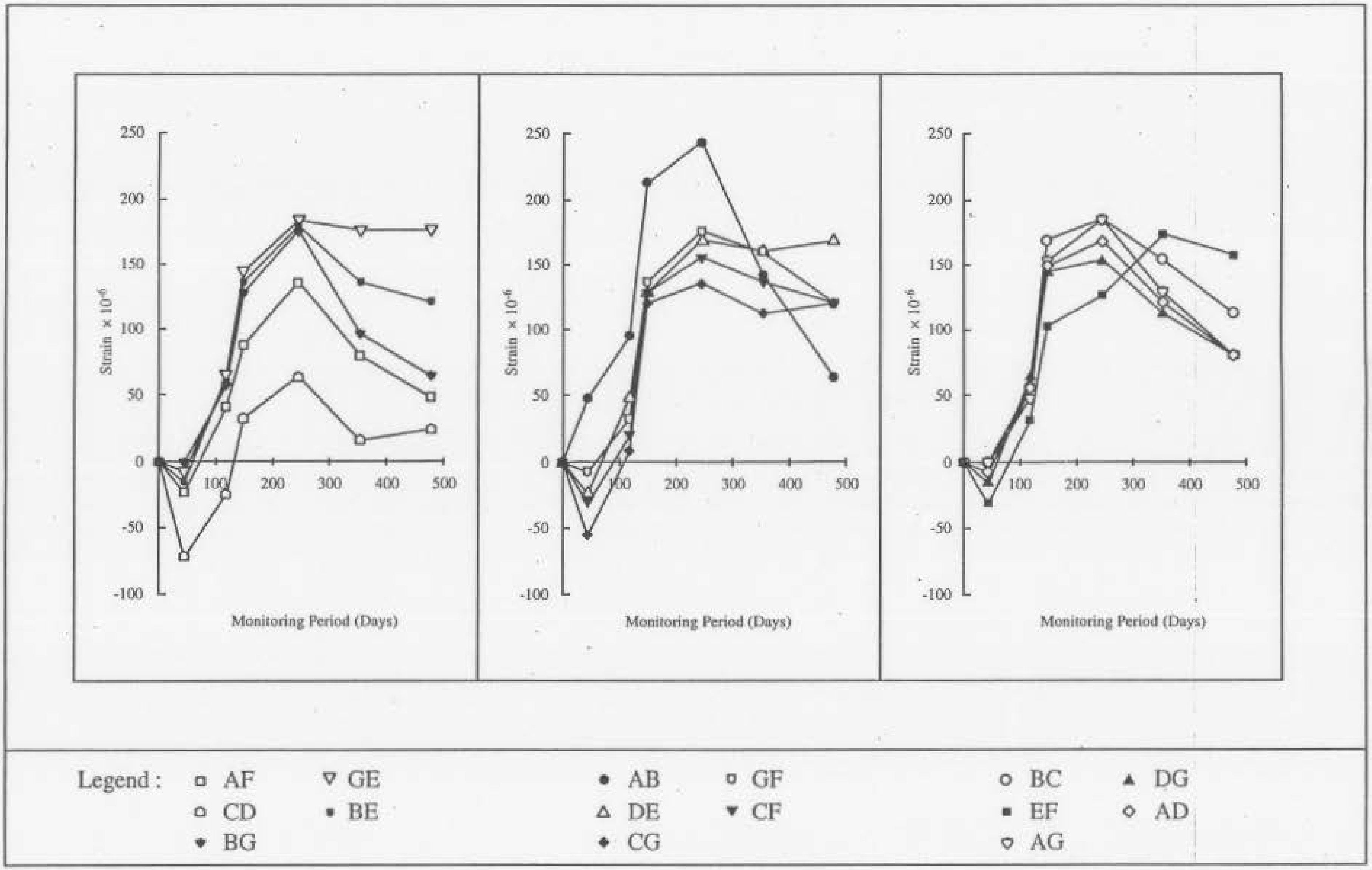

Figure 12 - Results of Insitu Measurement of Cracks by the PWCL for Panel H

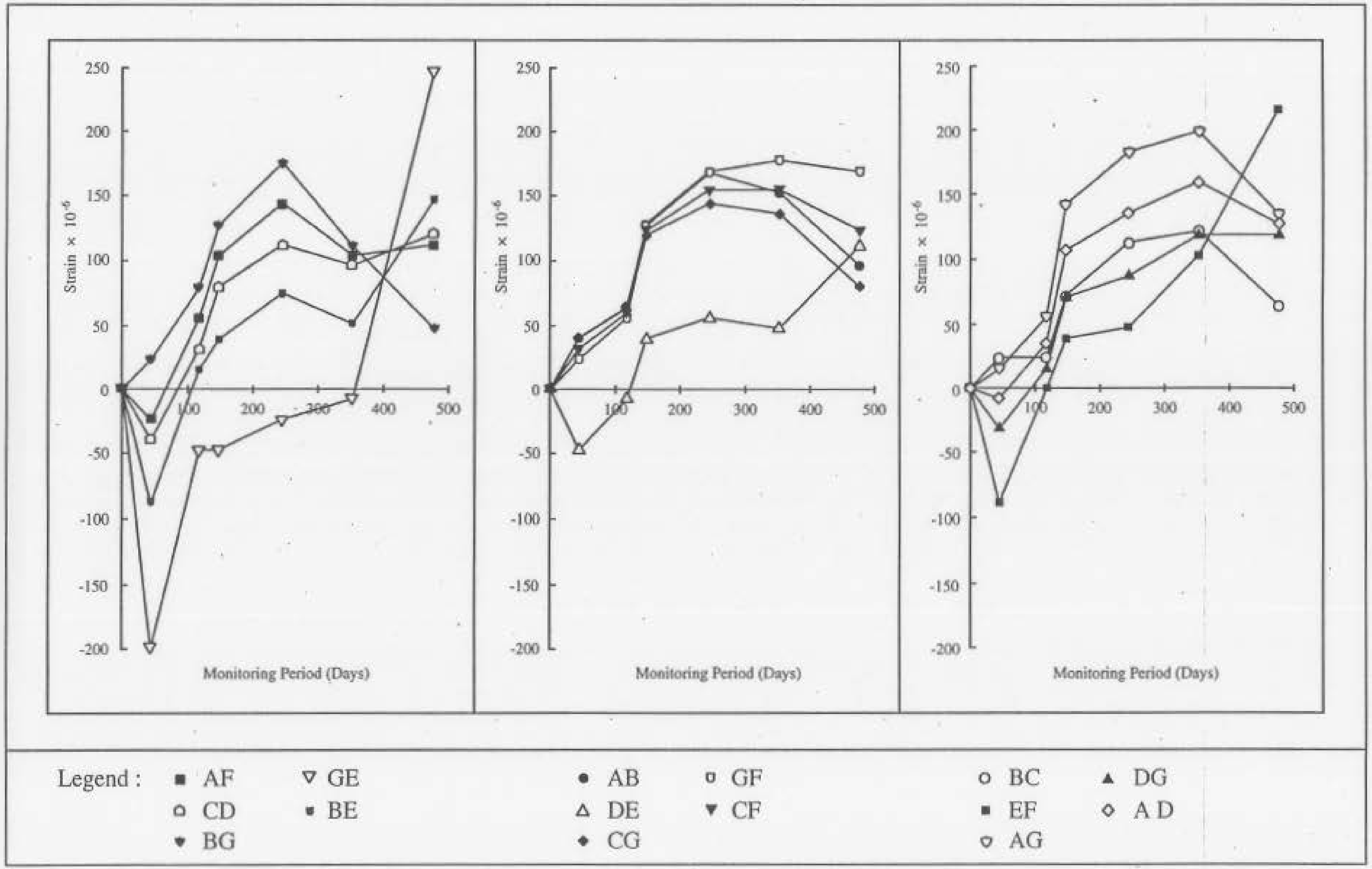

Figure 13 - Results of Insitu Measurement of Cracks by the PWCL for Panel J

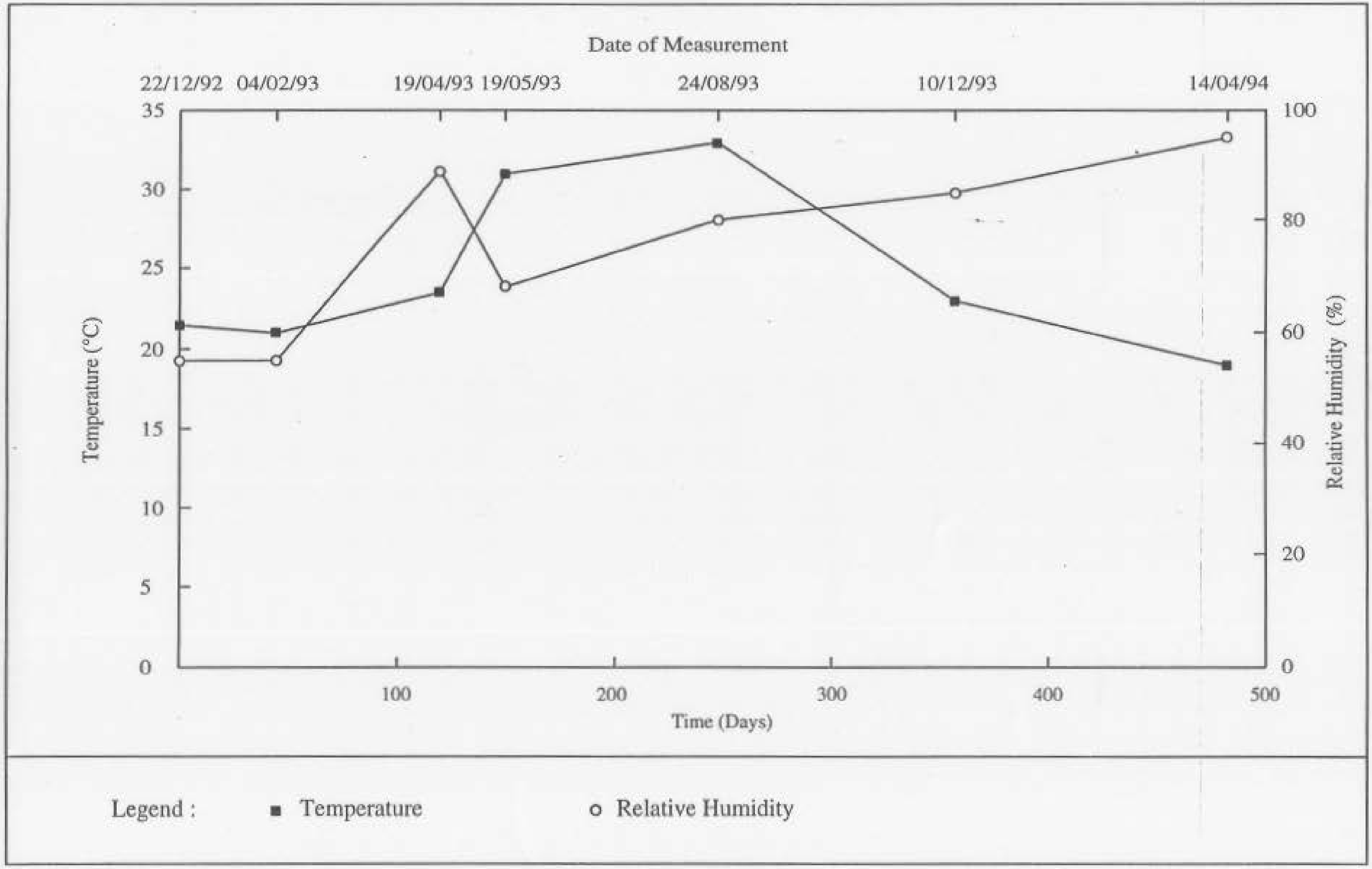

Figure 14 - Ambient Temperature and Relative Humidity at the Shek Wu Hui Sewage Treatment Plant on the Dates of Measurement

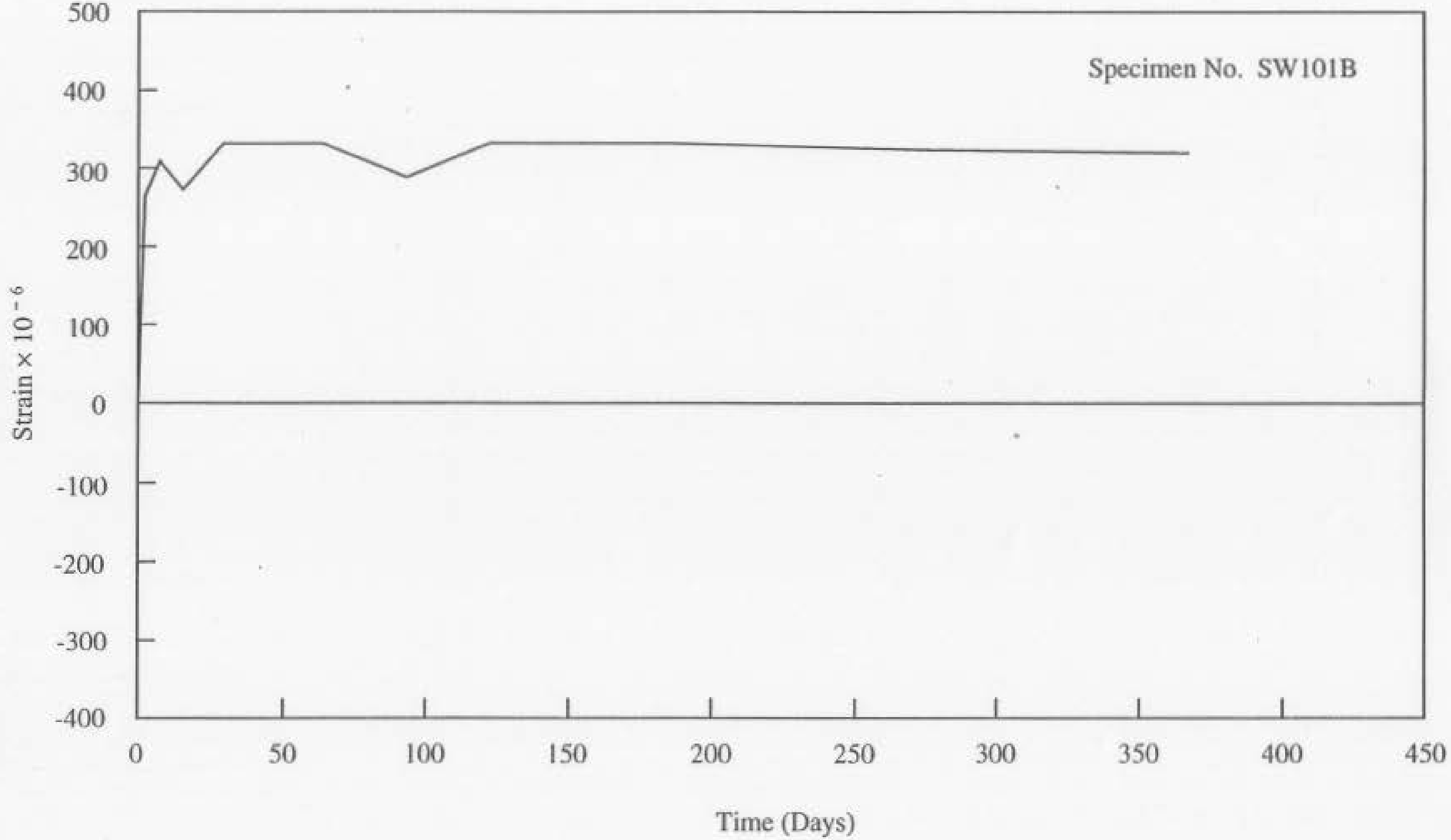

Figure 15 - Typical Expansion Test Results on Bar Specimen No. SW101B

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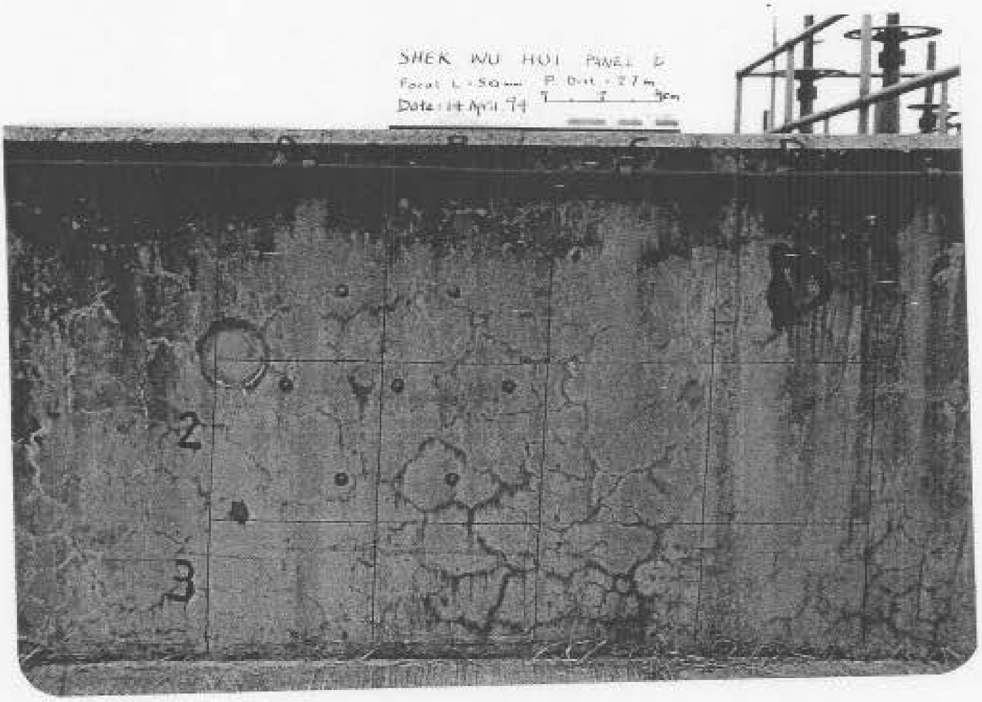

Plate 1 - Hexagonal Rosette of Demec Points at Panel D

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