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MFN 09-279

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Subject: **Response to NRC RAI Letter No. 299 Related to ESBWR Design Certification Application – DCD Tier 2 Section 3.8 – Seismic Category I Structures; RAI Numbers 3.8-107 S03**

The purpose of this letter is to submit the GE Hitachi Nuclear Energy (GEH) response to the U.S. Nuclear Regulatory Commission (NRC) Request for Additional Information (RAI) letter number 299 sent by NRC letter dated January 27, 2009 (Reference 1). RAI Number 3.8-107 S03 is addressed in Enclosure 1.

If you have any questions or require additional information, please contact me.

Sincerely,

Richard E. Kingston

Richard E. Kingston
Vice President, ESBWR Licensing

D068
NRO

Reference:

1. MFN 09-099 Letter from U.S. Nuclear Regulatory Commission to Robert E. Brown, GEH, *Request For Additional Information Letter No. 299 Related to ESBWR Design Certification* dated January 27, 2009

Enclosure:

1. Response to NRC RAI Letter No. 299 Related to ESBWR Design Certification Application - DCD Tier 2 Section 3.8 – Seismic Category I Structures; RAI Numbers 3.8-107 S03

cc:	AE Cubbage	USNRC (with enclosures)
	JG Head	GEH/Wilmington (with enclosures)
	DH Hinds	GEH/Wilmington (with enclosures)
	eDRF Section	0000-0099-3093 (RAI 3.8-107 S03)

ENCLOSURE 1

MFN 09-279

Response to NRC RAI Letter No. 299
Related to ESBWR Design Certification Application[1]

DCD Tier 2 Section 3.8 – Seismic Category I Structures

RAI Number 3.8-107 S03

[1] Original Response, Supplement 1 and Supplement 2 previously submitted under MFNs 06-416, 06-416, Supplement 2, 08-432 and 08-432, Supplement 1 without attachments are included to provide historical continuity during review.

NRC RAI 3.8-107

General Electric, through its contractor, Shimizu Corporation of Japan, carried out elastic analyses of the complete nuclear island structure, including the reinforced concrete containment vessel (RCCV) for separate load conditions using a static NASTRAN finite element model. The seismic loads were imposed as inertia loads corresponding to the element mass and seismically induced acceleration values (obtained from a separate seismic analysis) applicable to the location of the element. Internal element loads for all the finite elements in the complete structure for a specific applied load are stored in a computer file. For each applied load, a specific file is produced. These computer files are used as input files along with the rules for combining the individual load files to a postprocessor software called SSDP. SSDP assumes that linear superposition applies between different load combinations. Also provided as input information to the SSDP are the top, bottom and shear reinforcement areas associated with each finite element. It is not clear how the tangential shear reinforcements are treated in the SSDP package. In the post processing phase, SSDP checks demand against available reinforcement areas.

During the staff audit of ESBWR DCD Section 3.8 in July 2006, the staff wanted to have a clear sense of the governing loads (moments, forces, shear etc.) at the critical sections. Staff asked for and reviewed the SSDP validation package, but found that the validation package did not contain several items of interest to the staff. Staff requests that the following information be provided:

a) *How does SSDP flag instances where reinforcement provided is less than the demand?*

b) *How does SSDP identify governing load combinations and the corresponding loads on a given finite element?*

c) *How does SSDP apply the reinforced concrete codes used in the United States, such as ACI 349, ASME Section III, Div 2, and how are the code editions that are accepted by the NRC incorporated in the SSDP to keep it current?*

d) *How is the reinforcement pattern (radial and circumferential or rectangular grid) interpreted in the SSDP?*

e) *How does the SSDP identify critical sections of a structure?*

f) *In the reinforced concrete containment structure, how does SSDP evaluate the tangential shear stress to demonstrate compliance with the ASME Code?*

GEH Response

a) In the post-processing routine of the SSDP-2D, the maximum calculated stresses are compared with the allowable stresses, and stress ratios, i.e., ratio of calculated stress to allowable stress, are calculated. The maximum stress ratios obtained can be plotted on the finite element meshes as shown in Figure 3.8-107(1). In the figure, stress ratios exceeding 1.0, i.e., the maximum stress is larger than the allowable, are identified in a different color. This procedure is used to find the elements where reinforcement provided is less than the demand.

b) The ID numbers of the load combinations which generate the maximum stress ratios are also indicated in Figure 3.8-107(1). The governing load combinations are also shown on the figure.

c) SSDP-2D calculates the stresses of concrete and reinforcements for the axial forces and bending moments. Calculated stresses are compared with the allowable stresses specified in the applicable Codes as described in Items a) and b). SSDP-2D has supplemental subroutines for the tangential shear and transverse shear, and it is confirmed that the provided sections satisfy the Code requirements for shears. The validation of SSDP-2D provides confirmation that calculation results meet the requirements of Code editions which are specified for the project.

d) The directions of reinforcements, i.e., angles to a reference axis, are provided as input data. In the SSDP-2D, the reference axis is set to the x-direction of the element coordinate system. The reinforcement is regarded as a material which has stiffness in only one direction which is defined in the input data.

e) Since SSDP-2D only has a function to calculate stresses, it cannot identify critical sections of a structure. However, critical sections can be found by plotting stress ratios in a structure like Figure 3.8-107 (1).

f) Same response as Item c).

Revised SSDP-2D validation report was provided in Attachment 3.8-107(1). This revised report supersedes the version submitted in response to RAI 3.7-55 provided to you in MFN 06-189.

1609 0.418 7021	1610 0.405 7001	1611 0.392 7011	1612 0.600 7001	1613 0.802 7001	1614 0.601 7001	1615 0.644 7001	1616 0.806 7001	1617 0.597 7001	1618 0.344 7001	1619 0.403 7001	1620 0.423 7021
1597 0.329 7021	1598 0.337 7001	1599 0.261 7011	1600 0.783 7001	1601 0.911 7001	1602 0.589 7001	1603 0.585 7001	1604 0.903 7001	1605 0.823 7001	1606 0.266 7011	1607 0.337 7001	1608 1.252 7011
1585 0.327 7001	1586 0.369 7001	1587 0.774 7011	1588 0.628 7001	1589 0.916 7001	1590 0.980 7001	1591 0.971 7001	1592 0.910 7001	1593 0.594 7001	1594 0.821 7001	1595 0.368 7001	1596 0.330 7001
1573 0.266 7001	1574 1.287 7001	1575 0.593 7021	1576 0.794 7021	1577 0.720 7001	1578 1.179 7001	1579 1.182 7001	1580 0.719 7001	1581 0.797 7021	1582 0.589 7021	1583 0.275 7001	1584 0.272 7001
1561 0.199 7021	1562 0.257 7021	1563 0.720 7021	1564 0.974 7001	1565 0.364 7001	1566 1.209 7001	1567 1.194 7001	1568 0.358 7001	1569 0.971 7001	1570 0.717 7021	1571 0.230 7021	1572 0.205 7021
1549 0.196 7021	1550 0.214 7001	1551 0.695 7021	1552 0.945 7001	1553 0.433 7001	1554 1.231 7001	1555 1.230 7001	1556 0.437 7001	1557 0.950 7001	1558 0.691 7001	1559 0.240 7001	1560 0.200 7021
1537 0.198 7021	1538 0.226 7001	1539 0.558 7021	1540 0.816 7021	1541 0.645 7001	1542 1.129 7001	1543 1.121 7001	1544 0.648 7001	1545 0.808 7021	1546 0.560 7021	1547 0.220 7001	1548 0.203 7021
1525 0.267 7021	1526 0.279 7001	1527 0.575 7001	1528 0.567 7021	1529 0.551 7001	1530 0.925 7001	1531 0.928 7001	1532 0.545 7001	1533 0.563 7021	1534 0.590 7001	1535 0.277 7001	1536 0.281 7021
1513 0.320 7001	1514 0.318 7001	1515 0.299 7001	1516 0.516 7001					1521 0.506 7001	1522 0.288 7001	1523 0.316 7001	1524 0.366 7021
1501 0.413 7021	1502 0.327 7001	1503 0.332 7011	1504 0.490 7001	1505 0.716 7021	1506 0.735 7001	1507 0.734 7001	1508 0.715 7021	1509 0.491 7001	1510 0.332 7011	1511 0.289 7021	1512 0.419 7021

TOP: Element ID
MIDDLE: MAX STRESS RATIO
BOTTOM: LOAD ID

Figure 3.8-107 (1) Output of Maximum Stress Ratios (Sample)

DCD Impact

No DCD change was made in response to this RAI.

NRC RAI 3.8-107, Supplement 1

NRC Assessment Following the December 14, 2006 Audit

Provide additional information regarding the input data and processing of the SSDP postprocessor software.

Staff Assessment

Detailed staff review is needed to resolve. How would the evaluation procedure be affected by a change in the methodology to combine 3 directions of seismic response? GE's implementation of the 100/40/40 method does not comply with RG 1.92, as noted in a recent teleconference on 11/21/06.

GEH Response

The following study shows that the DCD process used to combine stresses produces results that are higher than those using the SRSS and RG 1.92 Load Factored approach. Since the SRSS method is GE's alternative to the present method, the intent of RG 1.92 to use conservative approaches in obtaining final stresses is met.

1. Procedure to Validate the DCD 100/40/40 Method

Step 1. Element Forces and Moment (NASTRAN Results)

The evaluations shown below are performed using NASTRAN results indicated in the DCD, Rev. 1.

Table 3.8-107(1) Example (referred from DCD Table 3G.1-25)

Element ID		Nx (MN/m)	Ny (MN/m)	Nxy (MN/m)	Mx (MNm/m)	My (MNm/m)	Mxy (MNm/m)	Qx (MN/m)	Qy (MN/m)
1824	OTHR	0.748	-2.802	0.003	0.784	4.585	0.021	-0.018	1.986
	TEMP	1.981	-2.824	0.082	-4.322	-7.438	0.022	-0.082	-1.354
	EQEW	0.071	0.451	7.426	-0.033	-0.119	0.094	-0.059	-0.064
	EQNS	0.906	6.607	-0.267	-0.034	-0.345	-0.011	0.003	-0.240
	EQZ	0.327	3.634	0.042	0.074	0.449	0.000	0.002	0.092
	EQT	0.002	-0.002	1.125	-0.003	-0.005	-0.013	-0.004	-0.003
	SPKW	-0.581	0.147	-0.037	-0.044	0.047	-0.002	0.005	0.063
	SPKN	-0.022	-0.020	0.071	0.051	-0.010	0.003	-0.013	0.041

Note:

- OTHR: Loads other than temperature and seismic loads
- TEMP: Temperature loads
- EQEW: Horizontal seismic loads in the EW direction
- EQNS: Horizontal seismic loads in the NS direction
- EQZ: Vertical seismic loads
- EQT: Torsional seismic loads
- SPKW: Dynamic soil pressure during a horizontal earthquake in the EW direction
- SPKN: Dynamic soil pressure during a horizontal earthquake in the NS direction

Step 2. Combination of Element Forces and Moment for Loads Excluding Seismic Loads

algebraic sum considering thermal ratios

$$F_{OT} = F_{OTHR} + \alpha F_{TEMP}$$

where,

F_{OTHR} : Element force or moment due to OTHR

F_{TEMP} : Element force or moment due to TEMP

α : Thermal ratio

Table 3.8-107(2) Example of Combination

Element ID		Nx (MN/m)	Ny (MN/m)	Nxy (MN/m)	Mx (MNm/m)	My (MNm/m)	Mxy (MNm/m)	Qx (MN/m)	Qy (MN/m)
1824	OTHR	0.748	-2.802	0.003	0.784	4.585	0.021	-0.018	1.986
	TEMP	1.981	-2.824	0.082	-4.322	-7.438	0.022	-0.082	-1.354
	Thermal ratio	1.690	0.140	1.000	0.160	0.290	1.000	-0.150	0.240
	TEMP'	3.348	-0.395	0.082	-0.692	-2.157	0.022	0.012	-0.325
	F_{OT}	4.096	-3.197	0.085	0.092	2.428	0.043	-0.006	1.661

Step 3. Combination of Element Forces and Moment for Seismic Loads

(1) SRSS Method

$$F_{NS} = |F_{EQNS}| + |F_{SPKN}|$$

$$F_{EW} = |F_{EQEW}| + |F_{SPKW}|$$

$$F_{SRSS} = \sqrt{F_{NS}^2 + F_{EW}^2 + F_Z^2 + F_T^2}$$

where,

F_{EQEW} : Element force or moment due to EQEW

F_{EQNS} : Element force or moment due to EQNS

F_{SPKW} : Element force or moment due to SPKW

F_{SPKN} : Element force or moment due to SPKN

F_Z : Element force or moment due to EQZ

F_T : Element force or moment due to EQT

Table 3.8-107(3) Example of Combination

Element ID		Nx (MN/m)	Ny (MN/m)	Nxy (MN/m)	Mx (MNm/m)	My (MNm/m)	Mxy (MNm/m)	Qx (MN/m)	Qy (MN/m)
1824	EQEW	0.071	0.451	7.426	-0.033	-0.119	0.094	-0.059	-0.064
	EQNS	0.906	6.607	-0.267	-0.034	-0.345	-0.011	0.003	-0.240
	EQZ	0.327	3.634	0.042	0.074	0.449	0.000	0.002	0.092
	EQT	0.002	-0.002	1.125	-0.003	-0.005	-0.013	-0.004	-0.003
	SPKW	-0.581	0.147	-0.037	-0.044	0.047	-0.002	0.005	0.063
	SPKN	-0.022	-0.020	0.071	0.051	-0.010	0.003	-0.013	0.041
	F_{EW}	0.652	0.598	7.463	0.077	0.166	0.096	0.064	0.127
	F_{NS}	0.928	6.627	0.338	0.085	0.355	0.014	0.016	0.281
	F_{SRSS}	1.180	7.582	7.555	0.137	0.596	0.098	0.066	0.322

(2) RG 1.92 Load Factored Method

$$F_{NS} = |F_{EQNS}| + |F_{SPKN}|$$

$$F_{EW} = |F_{EQEW}| + |F_{SPKW}|$$

Combination by 100/40/40 method

$$F_{LF1} = 1.0|F_{NS}| + 0.4|F_{EW}| + 0.4|F_Z| + 1.0|F_T|$$

$$F_{LF2} = 0.4|F_{NS}| + 1.0|F_{EW}| + 0.4|F_Z| + 1.0|F_T|$$

$$F_{LF3} = 0.4|F_{NS}| + 0.4|F_{EW}| + 1.0|F_Z| + 0.4|F_T|$$

$$F_{LF} = \max(F_{LF1}, F_{LF2}, F_{LF3})$$

Table 3.8-107(4) Example of Combination

Element ID		Nx (MN/m)	Ny (MN/m)	Nxy (MN/m)	Mx (MNm/m)	My (MNm/m)	Mxy (MNm/m)	Qx (MN/m)	Qy (MN/m)
1824	EQEW	0.071	0.451	7.426	-0.033	-0.119	0.094	-0.059	-0.064
	EQNS	0.906	6.607	-0.267	-0.034	-0.345	-0.011	0.003	-0.240
	EQZ	0.327	3.634	0.042	0.074	0.449	0.000	0.002	0.092
	EQT	0.002	-0.002	1.125	-0.003	-0.005	-0.013	-0.004	-0.003
	SPKW	-0.581	0.147	-0.037	-0.044	0.047	-0.002	0.005	0.063
	SPKN	-0.022	-0.020	0.071	0.051	-0.010	0.003	-0.013	0.041
	F_{EW}	0.652	0.598	7.463	0.077	0.166	0.096	0.064	0.127
	F_{NS}	0.928	6.627	0.338	0.085	0.355	0.014	0.016	0.281
	F_{LF1}	1.322	8.322	4.465	0.148	0.606	0.065	0.046	0.372
	F_{LF2}	1.156	4.704	8.740	0.144	0.493	0.115	0.075	0.279
	F_{LF3}	0.960	6.525	3.612	0.140	0.659	0.049	0.036	0.256
	F_{LF}	1.322	8.322	8.740	0.148	0.659	0.115	0.075	0.372

(3) DCD 100/40/40 Method

Element forces and moments for seismic loads are combined in accordance with Table 3.8-107(5).

Table 3.8-107(5) DCD 100/40/40 Method

Combination No.	Seismic Load												Dynamic Increment of Soil Pressure					
1	+	1.0	EQEW	+	0.4	EQNS	+	0.4	EQZ	+	1.0	EQT	+	1.0	SPKW	+	0.4	SPKN
2	+	1.0	EQEW	+	0.4	EQNS	+	0.4	EQZ	-	1.0	EQT	+	1.0	SPKW	+	0.4	SPKN
3	+	1.0	EQEW	+	0.4	EQNS	-	0.4	EQZ	+	1.0	EQT	+	1.0	SPKW	+	0.4	SPKN
4	+	1.0	EQEW	+	0.4	EQNS	-	0.4	EQZ	-	1.0	EQT	+	1.0	SPKW	+	0.4	SPKN
5	+	1.0	EQEW	-	0.4	EQNS	+	0.4	EQZ	+	1.0	EQT	+	1.0	SPKW	+	0.4	SPKN
6	+	1.0	EQEW	-	0.4	EQNS	+	0.4	EQZ	-	1.0	EQT	+	1.0	SPKW	+	0.4	SPKN
7	+	1.0	EQEW	-	0.4	EQNS	-	0.4	EQZ	+	1.0	EQT	+	1.0	SPKW	+	0.4	SPKN
8	+	1.0	EQEW	-	0.4	EQNS	-	0.4	EQZ	-	1.0	EQT	+	1.0	SPKW	+	0.4	SPKN
9	-	1.0	EQEW	+	0.4	EQNS	+	0.4	EQZ	+	1.0	EQT	+	1.0	SPKW	+	0.4	SPKN
10	-	1.0	EQEW	+	0.4	EQNS	+	0.4	EQZ	-	1.0	EQT	+	1.0	SPKW	+	0.4	SPKN
11	-	1.0	EQEW	+	0.4	EQNS	-	0.4	EQZ	+	1.0	EQT	+	1.0	SPKW	+	0.4	SPKN
12	-	1.0	EQEW	+	0.4	EQNS	-	0.4	EQZ	-	1.0	EQT	+	1.0	SPKW	+	0.4	SPKN
13	-	1.0	EQEW	-	0.4	EQNS	+	0.4	EQZ	+	1.0	EQT	+	1.0	SPKW	+	0.4	SPKN
14	-	1.0	EQEW	-	0.4	EQNS	+	0.4	EQZ	-	1.0	EQT	+	1.0	SPKW	+	0.4	SPKN
15	-	1.0	EQEW	-	0.4	EQNS	-	0.4	EQZ	+	1.0	EQT	+	1.0	SPKW	+	0.4	SPKN
16	-	1.0	EQEW	-	0.4	EQNS	-	0.4	EQZ	-	1.0	EQT	+	1.0	SPKW	+	0.4	SPKN
17	+	0.4	EQEW	+	1.0	EQNS	+	0.4	EQZ	+	1.0	EQT	+	0.4	SPKW	+	1.0	SPKN
18	+	0.4	EQEW	+	1.0	EQNS	+	0.4	EQZ	-	1.0	EQT	+	0.4	SPKW	+	1.0	SPKN
19	+	0.4	EQEW	+	1.0	EQNS	-	0.4	EQZ	+	1.0	EQT	+	0.4	SPKW	+	1.0	SPKN
20	+	0.4	EQEW	+	1.0	EQNS	-	0.4	EQZ	-	1.0	EQT	+	0.4	SPKW	+	1.0	SPKN
21	+	0.4	EQEW	-	1.0	EQNS	+	0.4	EQZ	+	1.0	EQT	+	0.4	SPKW	+	1.0	SPKN
22	+	0.4	EQEW	-	1.0	EQNS	+	0.4	EQZ	-	1.0	EQT	+	0.4	SPKW	+	1.0	SPKN
23	+	0.4	EQEW	-	1.0	EQNS	-	0.4	EQZ	+	1.0	EQT	+	0.4	SPKW	+	1.0	SPKN
24	+	0.4	EQEW	-	1.0	EQNS	-	0.4	EQZ	-	1.0	EQT	+	0.4	SPKW	+	1.0	SPKN
25	-	0.4	EQEW	+	1.0	EQNS	+	0.4	EQZ	+	1.0	EQT	+	0.4	SPKW	+	1.0	SPKN
26	-	0.4	EQEW	+	1.0	EQNS	+	0.4	EQZ	-	1.0	EQT	+	0.4	SPKW	+	1.0	SPKN
27	-	0.4	EQEW	+	1.0	EQNS	-	0.4	EQZ	+	1.0	EQT	+	0.4	SPKW	+	1.0	SPKN
28	-	0.4	EQEW	+	1.0	EQNS	-	0.4	EQZ	-	1.0	EQT	+	0.4	SPKW	+	1.0	SPKN
29	-	0.4	EQEW	-	1.0	EQNS	+	0.4	EQZ	+	1.0	EQT	+	0.4	SPKW	+	1.0	SPKN
30	-	0.4	EQEW	-	1.0	EQNS	+	0.4	EQZ	-	1.0	EQT	+	0.4	SPKW	+	1.0	SPKN
31	-	0.4	EQEW	-	1.0	EQNS	-	0.4	EQZ	+	1.0	EQT	+	0.4	SPKW	+	1.0	SPKN
32	-	0.4	EQEW	-	1.0	EQNS	-	0.4	EQZ	-	1.0	EQT	+	0.4	SPKW	+	1.0	SPKN
33	+	0.4	EQEW	+	0.4	EQNS	+	1.0	EQZ	+	0.4	EQT	+	0.4	SPKW	+	0.4	SPKN
34	+	0.4	EQEW	+	0.4	EQNS	+	1.0	EQZ	-	0.4	EQT	+	0.4	SPKW	+	0.4	SPKN
35	+	0.4	EQEW	+	0.4	EQNS	-	1.0	EQZ	+	0.4	EQT	+	0.4	SPKW	+	0.4	SPKN
36	+	0.4	EQEW	+	0.4	EQNS	-	1.0	EQZ	-	0.4	EQT	+	0.4	SPKW	+	0.4	SPKN
37	+	0.4	EQEW	-	0.4	EQNS	+	1.0	EQZ	+	0.4	EQT	+	0.4	SPKW	+	0.4	SPKN
38	+	0.4	EQEW	-	0.4	EQNS	+	1.0	EQZ	-	0.4	EQT	+	0.4	SPKW	+	0.4	SPKN
39	+	0.4	EQEW	-	0.4	EQNS	-	1.0	EQZ	+	0.4	EQT	+	0.4	SPKW	+	0.4	SPKN
40	+	0.4	EQEW	-	0.4	EQNS	-	1.0	EQZ	-	0.4	EQT	+	0.4	SPKW	+	0.4	SPKN
41	-	0.4	EQEW	+	0.4	EQNS	+	1.0	EQZ	+	0.4	EQT	+	0.4	SPKW	+	0.4	SPKN
42	-	0.4	EQEW	+	0.4	EQNS	+	1.0	EQZ	-	0.4	EQT	+	0.4	SPKW	+	0.4	SPKN
43	-	0.4	EQEW	+	0.4	EQNS	-	1.0	EQZ	+	0.4	EQT	+	0.4	SPKW	+	0.4	SPKN
44	-	0.4	EQEW	+	0.4	EQNS	-	1.0	EQZ	-	0.4	EQT	+	0.4	SPKW	+	0.4	SPKN
45	-	0.4	EQEW	-	0.4	EQNS	+	1.0	EQZ	+	0.4	EQT	+	0.4	SPKW	+	0.4	SPKN
46	-	0.4	EQEW	-	0.4	EQNS	+	1.0	EQZ	-	0.4	EQT	+	0.4	SPKW	+	0.4	SPKN
47	-	0.4	EQEW	-	0.4	EQNS	-	1.0	EQZ	+	0.4	EQT	+	0.4	SPKW	+	0.4	SPKN
48	-	0.4	EQEW	-	0.4	EQNS	-	1.0	EQZ	-	0.4	EQT	+	0.4	SPKW	+	0.4	SPKN

Table 3.8-107(6) Example of Combination

Element ID		Nx (MN/m)	Ny (MN/m)	Nxy (MN/m)	Mx (MNm/m)	My (MNm/m)	Mxy (MNm/m)	Qx (MN/m)	Qy (MN/m)
1824	EQEW	0.071	0.451	7.426	-0.033	-0.119	0.094	-0.059	-0.064
	EQNS	0.906	6.607	-0.267	-0.034	-0.345	-0.011	0.003	-0.240
	EQZ	0.327	3.634	0.042	0.074	0.449	0.000	0.002	0.092
	EQT	0.002	-0.002	1.125	-0.003	-0.005	-0.013	-0.004	-0.003
	SPKW	-0.581	0.147	-0.037	-0.044	0.047	-0.002	0.005	0.063
	SPKN	-0.022	-0.020	0.071	0.051	-0.010	0.003	-0.013	0.041
	1 FDCD	-0.024	4.684	8.452	-0.044	-0.039	0.076	-0.061	-0.047
	2 FDCD	-0.028	4.688	6.202	-0.038	-0.029	0.102	-0.053	-0.041
	3 FDCD	-0.285	1.777	8.419	-0.103	-0.399	0.076	-0.063	-0.120
	4 FDCD	-0.289	1.781	6.169	-0.097	-0.389	0.102	-0.055	-0.114
	5 FDCD	-0.748	-0.601	8.666	-0.016	0.237	0.085	-0.064	0.145
	6 FDCD	-0.752	-0.597	6.416	-0.010	0.247	0.111	-0.056	0.151
	7 FDCD	-1.010	-3.508	8.632	-0.076	-0.123	0.085	-0.065	0.072
	8 FDCD	-1.014	-3.504	6.382	-0.070	-0.113	0.111	-0.057	0.078
	9 FDCD	-0.166	3.782	-6.400	0.022	0.199	-0.112	0.057	0.081
	10 FDCD	-0.170	3.786	-8.650	0.028	0.209	-0.086	0.065	0.087
	11 FDCD	-0.427	0.875	-6.433	-0.037	-0.161	-0.112	0.055	0.008
	12 FDCD	-0.431	0.879	-8.683	-0.031	-0.151	-0.086	0.063	0.014
	13 FDCD	-0.890	-1.503	-6.186	0.050	0.475	-0.103	0.054	0.273
	14 FDCD	-0.894	-1.499	-8.436	0.056	0.485	-0.077	0.062	0.279
	15 FDCD	-1.152	-4.410	-6.220	-0.010	0.115	-0.103	0.053	0.200
	16 FDCD	-1.156	-4.406	-8.470	-0.004	0.125	-0.077	0.061	0.206
	17 FDCD	0.813	8.278	3.901	0.013	-0.209	0.016	-0.035	-0.166
	18 FDCD	0.809	8.282	1.651	0.019	-0.199	0.042	-0.027	-0.160
	19 FDCD	0.551	5.371	3.868	-0.046	-0.568	0.016	-0.036	-0.239
	20 FDCD	0.547	5.375	1.618	-0.040	-0.558	0.042	-0.028	-0.233
	21 FDCD	-0.999	-4.936	4.435	0.081	0.481	0.038	-0.041	0.314
	22 FDCD	-1.003	-4.932	2.185	0.087	0.491	0.064	-0.033	0.320
	23 FDCD	-1.261	-7.843	4.402	0.022	0.122	0.038	-0.042	0.241
	24 FDCD	-1.265	-7.839	2.152	0.028	0.132	0.064	-0.034	0.247
	25 FDCD	0.756	7.917	-2.039	0.039	-0.114	-0.059	0.012	-0.114
	26 FDCD	0.752	7.921	-4.289	0.045	-0.104	-0.033	0.020	-0.108
	27 FDCD	0.494	5.010	-2.073	-0.020	-0.473	-0.059	0.011	-0.188
	28 FDCD	0.490	5.014	-4.323	-0.014	-0.463	-0.033	0.019	-0.182
	29 FDCD	-1.056	-5.297	-1.505	0.107	0.576	-0.037	0.006	0.366
	30 FDCD	-1.060	-5.293	-3.755	0.113	0.586	-0.011	0.014	0.372
	31 FDCD	-1.318	-8.204	-1.539	0.048	0.217	-0.037	0.005	0.292
	32 FDCD	-1.322	-8.200	-3.789	0.054	0.227	-0.011	0.013	0.298
	33 FDCD	0.477	6.507	3.369	0.049	0.276	0.028	-0.025	0.011
	34 FDCD	0.476	6.509	2.469	0.051	0.280	0.039	-0.022	0.013
	35 FDCD	-0.177	-0.761	3.285	-0.099	-0.622	0.028	-0.029	-0.173
	36 FDCD	-0.178	-0.759	2.385	-0.097	-0.618	0.039	-0.026	-0.171
	37 FDCD	-0.247	1.222	3.583	0.076	0.552	0.037	-0.028	0.203
	38 FDCD	-0.249	1.223	2.683	0.078	0.556	0.048	-0.024	0.205
	39 FDCD	-0.901	-6.046	3.499	-0.072	-0.346	0.037	-0.032	0.019
	40 FDCD	-0.903	-6.045	2.599	-0.070	-0.342	0.048	-0.028	0.021
	41 FDCD	0.421	6.146	-2.572	0.075	0.371	-0.047	0.022	0.062
	42 FDCD	0.419	6.148	-3.472	0.078	0.375	-0.036	0.025	0.064
	43 FDCD	-0.233	-1.122	-2.656	-0.073	-0.527	-0.047	0.018	-0.122
	44 FDCD	-0.235	-1.120	-3.556	-0.070	-0.523	-0.036	0.021	-0.120
	45 FDCD	-0.304	0.861	-2.358	0.102	0.647	-0.038	0.020	0.254
	46 FDCD	-0.306	0.862	-3.258	0.105	0.651	-0.028	0.023	0.256
	47 FDCD	-0.958	-6.407	-2.442	-0.046	-0.251	-0.038	0.016	0.070
	48 FDCD	-0.960	-6.406	-3.342	-0.043	-0.247	-0.028	0.019	0.072

Step 4. Combination of Element Forces and Moment for Seismic Loads and Other Loads

(1) SRSS Method and DG 1.92 Load Factored Method

Following two cases are considered.

	Sign of element force and moment for other loads	Sign of element force and moment for seismic loads
Maximized case	+	+
	-	-
Minimized case	+	-
	-	+

(SRSS method)

$_{MX}F_{SRSS} = F_{OT} + F_{SRSS}$, if $F_{OT} < 0$, $_{MX}F_{SRSS} = F_{OT} - F_{SRSS}$

$_{MN}F_{SRSS} = F_{OT} - F_{SRSS}$, if $F_{OT} < 0$, $_{MN}F_{SRSS} = F_{OT} + F_{SRSS}$

(RG 1.92 Load Factored method)

$_{MX}F_{LF} = F_{OT} + F_{LF}$, if $F_{OT} < 0$, $_{MX}F_{LF} = F_{OT} - F_{LF}$

$_{MN}F_{LF} = F_{OT} - F_{LF}$, if $F_{OT} < 0$, $_{MN}F_{LF} = F_{OT} + F_{LF}$

Table 3.8-107(7) Example of Combination

Element ID		Nx (MN/m)	Ny (MN/m)	Nxy (MN/m)	Mx (MNm/m)	My (MNm/m)	Mxy (MNm/m)	Qx (MN/m)	Qy (MN/m)
1824	F_{OT}	0.946	-3.141	0.085	0.395	3.246	0.043	-0.006	1.485
	F_{SRSS}	1.180	7.582	7.555	0.137	0.596	0.098	0.066	0.322
	F_{LF}	1.322	8.322	8.740	0.148	0.659	0.115	0.075	0.372
	$_{MX}F_{SRSS}$	2.126	-10.722	7.640	0.532	3.842	0.141	-0.072	1.807
	$_{MN}F_{SRSS}$	-0.234	4.441	-7.470	0.258	2.650	-0.055	0.060	1.163
	$_{MX}F_{LF}$	2.268	-11.463	8.825	0.543	3.906	0.158	-0.081	1.857
	$_{MN}F_{LF}$	-0.376	5.181	-8.655	0.247	2.587	-0.072	0.070	1.113

(2) DCD 100/40/40 Method

Element forces and moments for seismic loads combined with the 100/40/40 method are algebraically added to those for other loads.

$_{Ci}F_{DCD} = F_{OT} + {}_iF_{DCD}$, (i = 1~48)

Table 3.8-107(8) Example of Combination

Element ID		Nx (MN/m)	Ny (MN/m)	Nxy (MN/m)	Mx (MNm/m)	My (MNm/m)	Mxy (MNm/m)	Qx (MN/m)	Qy (MN/m)
1824	F_{OT}	4.096	-3.197	0.085	0.092	2.428	0.043	-0.006	1.661
	$_{C1}F_{DCD}$	4.072	1.487	8.537	0.049	2.389	0.119	-0.067	1.614
	$_{C2}F_{DCD}$	4.068	1.491	6.287	0.055	2.399	0.145	-0.059	1.620
	$_{C3}F_{DCD}$	3.811	-1.420	8.504	-0.010	2.029	0.119	-0.069	1.541
	$_{C4}F_{DCD}$	3.807	-1.416	6.254	-0.004	2.039	0.145	-0.061	1.547
	$_{C5}F_{DCD}$	3.347	-3.799	8.751	0.076	2.665	0.128	-0.069	1.806
	$_{C6}F_{DCD}$	3.343	-3.795	6.501	0.082	2.675	0.154	-0.061	1.812
	$_{C7}F_{DCD}$	3.086	-6.706	8.717	0.017	2.305	0.128	-0.071	1.733
	$_{C8}F_{DCD}$	3.082	-6.702	6.467	0.023	2.315	0.154	-0.063	1.739
	$_{C9}F_{DCD}$	3.930	0.585	-6.315	0.115	2.627	-0.069	0.051	1.742
	$_{C10}F_{DCD}$	3.926	0.589	-8.565	0.121	2.637	-0.043	0.059	1.748
	$_{C11}F_{DCD}$	3.669	-2.322	-6.348	0.056	2.267	-0.069	0.050	1.669
	$_{C12}F_{DCD}$	3.665	-2.318	-8.598	0.062	2.277	-0.043	0.058	1.675
	$_{C13}F_{DCD}$	3.205	-4.701	-6.101	0.142	2.903	-0.060	0.049	1.934
	$_{C14}F_{DCD}$	3.201	-4.697	-8.351	0.148	2.913	-0.034	0.057	1.940
	$_{C15}F_{DCD}$	2.944	-7.608	-6.135	0.083	2.543	-0.060	0.047	1.861
	$_{C16}F_{DCD}$	2.940	-7.604	-8.385	0.089	2.553	-0.034	0.055	1.867
	$_{C17}F_{DCD}$	4.909	5.080	3.986	0.105	2.219	0.059	-0.041	1.495
	$_{C18}F_{DCD}$	4.905	5.084	1.736	0.111	2.229	0.085	-0.033	1.501
	$_{C19}F_{DCD}$	4.647	2.173	3.953	0.046	1.860	0.059	-0.042	1.422
	$_{C20}F_{DCD}$	4.643	2.177	1.703	0.052	1.870	0.085	-0.034	1.428
	$_{C21}F_{DCD}$	3.097	-8.134	4.520	0.173	2.909	0.081	-0.047	1.975
	$_{C22}F_{DCD}$	3.093	-8.130	2.270	0.179	2.919	0.107	-0.039	1.981
	$_{C23}F_{DCD}$	2.835	-11.041	4.487	0.114	2.550	0.081	-0.048	1.902
	$_{C24}F_{DCD}$	2.831	-11.037	2.237	0.120	2.560	0.107	-0.040	1.908
	$_{C25}F_{DCD}$	4.852	4.720	-1.954	0.132	2.314	-0.016	0.007	1.547
	$_{C26}F_{DCD}$	4.848	4.724	-4.204	0.138	2.324	0.010	0.015	1.553
	$_{C27}F_{DCD}$	4.590	1.812	-1.988	0.072	1.955	-0.016	0.005	1.473
	$_{C28}F_{DCD}$	4.586	1.816	-4.238	0.078	1.965	0.010	0.013	1.479
	$_{C29}F_{DCD}$	3.040	-8.494	-1.420	0.200	3.004	0.006	0.001	2.027
	$_{C30}F_{DCD}$	3.036	-8.490	-3.670	0.206	3.014	0.032	0.009	2.033
	$_{C31}F_{DCD}$	2.778	-11.402	-1.454	0.140	2.645	0.006	-0.001	1.953
	$_{C32}F_{DCD}$	2.774	-11.398	-3.704	0.146	2.655	0.032	0.007	1.959
	$_{C33}F_{DCD}$	4.573	3.310	3.454	0.141	2.704	0.071	-0.031	1.672
	$_{C34}F_{DCD}$	4.572	3.311	2.554	0.144	2.708	0.082	-0.028	1.674
	$_{C35}F_{DCD}$	3.919	-3.958	3.370	-0.007	1.806	0.071	-0.035	1.488
	$_{C36}F_{DCD}$	3.918	-3.957	2.470	-0.004	1.810	0.082	-0.032	1.490
	$_{C37}F_{DCD}$	3.848	-1.976	3.668	0.168	2.980	0.080	-0.033	1.864
	$_{C38}F_{DCD}$	3.847	-1.974	2.768	0.171	2.984	0.091	-0.030	1.866
	$_{C39}F_{DCD}$	3.194	-9.244	3.584	0.020	2.082	0.080	-0.037	1.680
	$_{C40}F_{DCD}$	3.193	-9.242	2.684	0.023	2.086	0.091	-0.034	1.682
	$_{C41}F_{DCD}$	4.516	2.949	-2.487	0.168	2.799	-0.004	0.016	1.723
	$_{C42}F_{DCD}$	4.515	2.951	-3.387	0.170	2.803	0.007	0.020	1.725
	$_{C43}F_{DCD}$	3.862	-4.319	-2.571	0.020	1.901	-0.004	0.012	1.539
	$_{C44}F_{DCD}$	3.861	-4.317	-3.471	0.022	1.905	0.007	0.016	1.541
	$_{C45}F_{DCD}$	3.792	-2.337	-2.273	0.195	3.075	0.005	0.014	1.915
	$_{C46}F_{DCD}$	3.790	-2.335	-3.173	0.197	3.079	0.015	0.017	1.917
	$_{C47}F_{DCD}$	3.138	-9.605	-2.357	0.047	2.177	0.005	0.010	1.731
	$_{C48}F_{DCD}$	3.136	-9.603	-3.257	0.049	2.181	0.015	0.013	1.733

Step 5. Stress Calculation by SSDP-2D

Stresses of concrete and rebars are calculated for four combinations obtained in Step 4 by SSDP-2D. Calculations are performed for the RCCV elements whose results are included in DCD. Design load combinations for which calculations are performed are "LOCA+SSE" (CV-11a and CV-11b in Table 3G.1-10 of DCD).

Step 6. Comparison of Calculated Stresses

Stresses calculated in Step 5 are compared with those shown in the DCD, Rev.1 to demonstrate that the DCD 100/40/40 method predicts higher stresses than the SRSS method, thus meeting the intent of RG 1.92 R2.

2. Evaluation Results

Figures 3.8-107(1) through 3.8-107(12) show the comparisons of the stresses calculated by the SRSS method or the RG 1.92 Load Factored method described above and by the 100/40/40 method used for the current DCD design ("DCD method").

Circles indicated in each figure indicate the calculated stresses for 45 RCCV elements whose results are included in the DCD. X coordinate of a circle is the stress ratio by the DCD method, i.e., the ratio of the stress calculated by the DCD method to the allowable stress. Y coordinate is the stress ratio by the SRSS method. Namely, if a circle is plotted below the line of Y=X, which is drawn in each figure, the stress calculated by the DCD method is larger than the stress by the SRSS method.

Calculation conditions for each figure are summarized below.

Figure #	SRSS method	Load Combination
3.8-107(1)	SRSS-MAX Stresses for SRSS method calculated using ${}_{MX}F_{SRSS}$	LOCA+SSE; 6min. after, winter Load ID = 7241 (CV-11a in DCD)
3.8-107(2)		LOCA+SSE; 72hr. after, winter Load ID = 7441 (CV-11b in DCD)
3.8-107(3)	SRSS-MIN Stresses for SRSS method calculated using ${}_{MN}F_{SRSS}$	LOCA+SSE; 6min. after, winter Load ID = 7241 (CV-11a in DCD)
3.8-107(4)		LOCA+SSE; 72hr. after, winter Load ID = 7441 (CV-11b in DCD)
3.8-107(5)	SRSS-BOUND Bounding values of SRSS-MAX and SRSS-MIN	LOCA+SSE; 6min. after, winter Load ID = 7241 (CV-11a in DCD)
3.8-107(6)		LOCA+SSE; 72hr. after, winter Load ID = 7441 (CV-11b in DCD)
3.8-107(7)	LFM-MAX Stresses for RG 1.92 Load Factored method calculated using ${}_{MX}F_{LF}$	LOCA+SSE; 6min. after, winter Load ID = 7241 (CV-11a in DCD)
3.8-107(8)		LOCA+SSE; 72hr. after, winter Load ID = 7441 (CV-11b in DCD)
3.8-107(9)	LFM-MIN Stresses for RG 1.92 Load Factored method calculated using ${}_{MN}F_{LF}$	LOCA+SSE; 6min. after, winter Load ID = 7241 (CV-11a in DCD)
3.8-107(10)		LOCA+SSE; 72hr. after, winter Load ID = 7441 (CV-11b in DCD)
3.8-107(11	LFM-BOUND Bounding values of LFM-MAX and LFM-MIN	LOCA+SSE; 6min. after, winter Load ID = 7241 (CV-11a in DCD)
3.8-107(12)		LOCA+SSE; 72hr. after, winter Load ID = 7441 (CV-11b in DCD)

Rebars 1 through 4 correspond to:

Rebar	RCCV wall/Pedestal	Suppression Pool Slab	Top Slab
1	Outside hoop rebar	Bottom radial rebar	Bottom N-S rebar
2	Inside hoop rebar	Top radial rebar	Top N-S rebar
3	Outside vertical rebar	Bottom circumferential rebar	Bottom E-W rebar
4	Inside vertical rebar	Top circumferential rebar	Top E-W rebar

As for the comparison between the SRSS-MAX and DCD methods (Figures 3.8-107(1) and (2)), concrete and shear tie stresses calculated by the DCD method are generally larger than those by the SRSS method. For the main bar stresses, although the stresses calculated by the SRSS method are larger than the DCD method results in several elements, it can be said that the DCD method gives the conservative value, in general.

The above tendency is more remarkable for the SRSS-MIN cases (Figures 3.8-107(3) and (4)). The results for the SRSS-BOUND cases are similar to the SRSS-MAX cases (Figures 3.8-107(5) and (6)).

As for the RG 1.92 Load Factored method (Figures 3.8-107(7) through (12)), the results are similar to those of the SRSS method, although calculated stresses are slightly larger than the SRSS results in general.

The above results are summarized in Tables 3.8-107(9) and (10). In the table, the difference of the stress ratio is classified into four groups as follows, and the number of elements included in each group is counted. As for main bars, since one element includes four rebars, (two layers) × (two directions), total number is four times of the number of element, 4×45=180.

$\Delta\alpha = \alpha_{SRSS} - \alpha_{DCD}$ or $\Delta\alpha = \alpha_{LF} - \alpha_{DCD}$

where,

α_{SRSS} : Stress ratio based on the SRSS method

α_{LF} : Stress ratio based on the RG 1.92 Load Factored method

α_{DCD} : Stress ratio based on the DCD 100/40/40 method

Group 1: $\Delta\alpha > 0.1$	(stress by the SRSS method or RG 1.92 Load Factored method is larger than that by the DCD 100/40/40 method.)
Group 2: $0.0 < \Delta\alpha \leq 0.1$	(stress by the SRSS method or RG 1.92 Load Factored method is slightly larger than that by the DCD 100/40/40 method.)
Group 3: $-0.1 < \Delta\alpha \leq 0.0$	(stress by the SRSS method or RG 1.92 Load Factored method is slightly less than that by the DCD 100/40/40 method.)
Group 4: $\Delta\alpha \leq -0.1$	(stress by the SRSS method or RG 1.92 Load Factored method is less than that by the DCD 100/40/40 method.)

Based on the table, the SRSS method underestimates the stresses of main bars in more than 60% (44.2+16.7=60.9) of total rebars, and the ratios are increased to 75% (53.3+21.1=74.4) for concrete stress and 85% (74.4+12.2=85.6) for shear tie. As for the Load Factored method, the results are similar to those of the SRSS method, although the ratios of stress underestimation are slightly reduced.

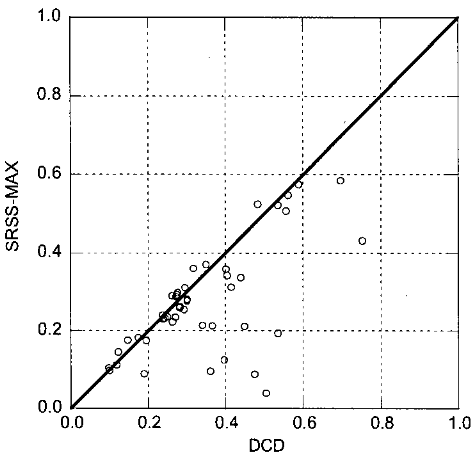
Therefore, it can be concluded that the DCD method of 100/40/40 combination meets the intent of RG 1.92 since the resulting stresses are mostly more conservative than the SRSS method and the RG 1.92 Load Factored method.

Table 3.8-107(9) Grouping of Comparison Results (SRSS Method)

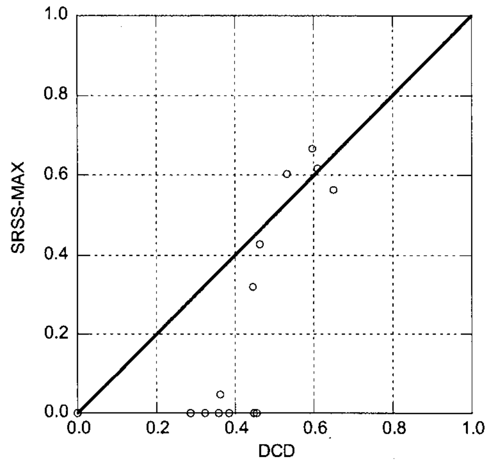
SRSS Method	Group (SRSS-DCD)	Concrete				Main Bar				Shear Tie			
		Load ID		Sum	%	Load ID		Sum	%	Load ID		Sum	%
		7241	7441			7241	7441			7241	7441		
SRSS-MAX	□□> 0.1	0	0	0	0.0	17	16	33	9.2	0	1	1	1.1
	0.0 < □□≤ 0.1	13	10	23	25.6	27	29	56	15.6	3	5	8	8.9
	-0.1 < □□≤ 0.0	19	29	48	53.3	62	60	122	33.9	34	33	67	74.4
	□□≤ -0.1	13	6	19	21.1	74	75	149	41.4	8	6	14	15.6
	Total	*45*	*45*	*90*		*180*	*180*	*360*		*45*	*45*	*90*	
SRSS-MIN	□□> 0.1	0	0	0	0.0	4	5	9	2.5	0	1	1	1.1
	0.0 < □□≤ 0.1	0	0	0	0.0	24	23	47	13.1	0	3	3	3.3
	-0.1 < □□≤ 0.0	14	16	30	33.3	78	78	156	43.3	32	31	63	70.0
	□□≤ -0.1	31	29	60	66.7	74	74	148	41.1	13	10	23	25.6
	Total	*45*	*45*	*90*		*180*	*180*	*360*		*45*	*45*	*90*	
SRSS-BOUND	□□> 0.1	0	0	0	0.0	21	21	42	11.7	0	2	2	2.2
	0.0 < □□≤ 0.1	13	10	23	25.6	49	50	99	27.5	3	7	10	11.1
	-0.1 < □□≤ 0.0	19	29	48	53.3	82	77	159	44.2	34	33	67	74.4
	□□≤ -0.1	13	6	19	21.1	28	32	60	16.7	8	3	11	12.2
	Total	*45*	*45*	*90*		*180*	*180*	*360*		*45*	*45*	*90*	

Table 3.8-107(10) Grouping of Comparison Results (RG 1.92 Load Factored Method)

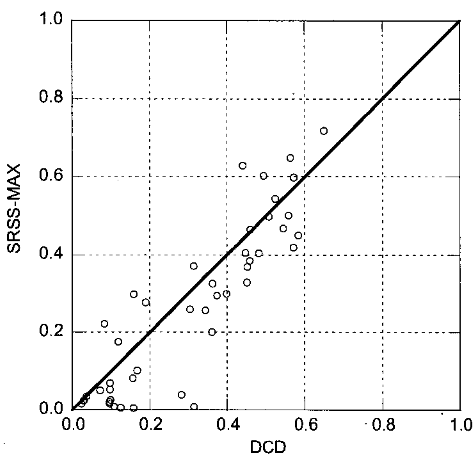
SRSS Method	Group (LFM-DCD)	Concrete				Main Bar				Shear Tie			
		Load ID		Sum	%	Load ID		Sum	%	Load ID		Sum	%
		7241	7441			7241	7441			7241	7441		
LFM-MAX	□□> 0.1	0	0	0	0.0	20	22	42	11.7	0	1	1	1.1
	0.0 < □□≤ 0.1	21	23	44	48.9	30	31	61	16.9	3	5	8	8.9
	-0.1 < □□≤ 0.0	14	16	30	33.3	63	59	122	33.9	34	33	67	74.4
	□□≤ -0.1	10	6	16	17.8	67	68	135	37.5	8	6	14	15.6
	Total	*45*	*45*	*90*		*180*	*180*	*360*		*45*	*45*	*90*	
LFM-MIN	□□> 0.1	0	0	0	0.0	9	14	23	6.4	0	2	2	2.2
	0.0 < □□≤ 0.1	0	0	0	0.0	32	24	56	15.6	1	2	3	3.3
	-0.1 < □□≤ 0.0	16	20	36	40.0	71	80	151	41.9	31	31	62	68.9
	□□≤ -0.1	29	25	54	60.0	68	62	130	36.1	13	10	23	25.6
	Total	*45*	*45*	*90*		*180*	*180*	*360*		*45*	*45*	*90*	
LFM-BOUND	□□> 0.1	0	0	0	0.0	29	35	64	17.8	0	3	3	3.3
	0.0 < □□≤ 0.1	21	23	44	48.9	58	52	110	30.6	4	6	10	11.1
	-0.1 < □□≤ 0.0	14	16	30	33.3	73	75	148	41.1	33	33	66	73.3
	□□≤ -0.1	10	6	16	17.8	20	18	38	10.6	8	3	11	12.2
	Total	*45*	*45*	*90*		*180*	*180*	*360*		*45*	*45*	*90*	



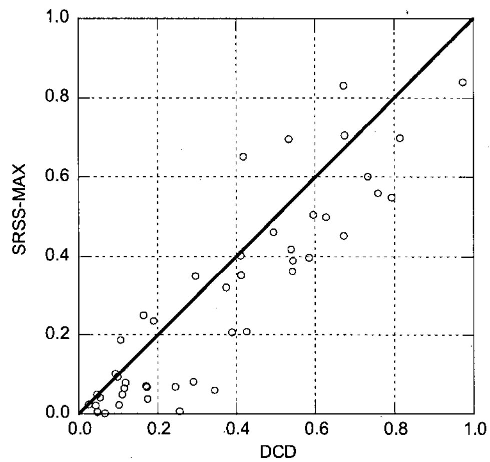
(a) Concrete



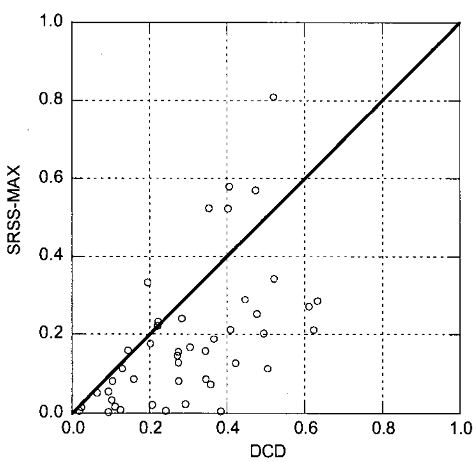
(b) Shear Tie



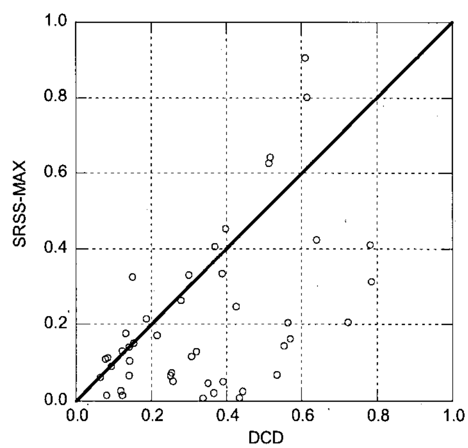
(c) Rebar 1



(d) Rebar 2

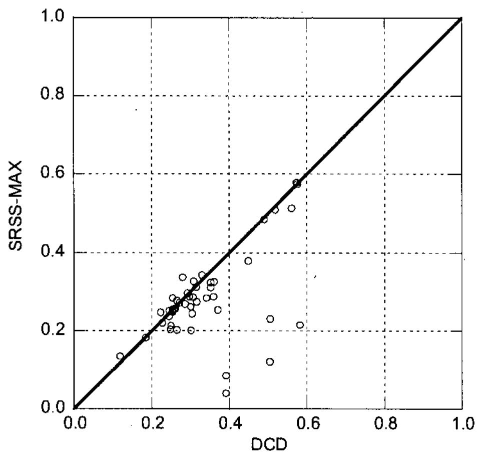


(e) Rebar 3

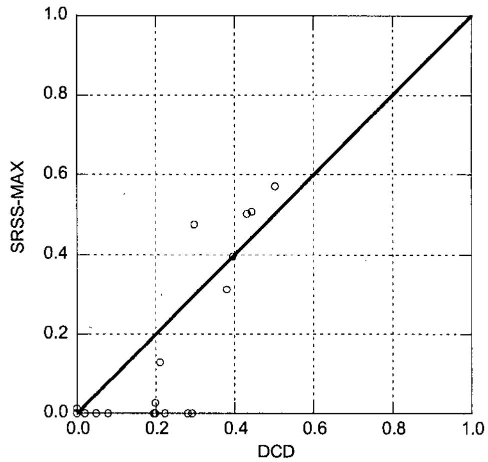


(f) Rebar 4

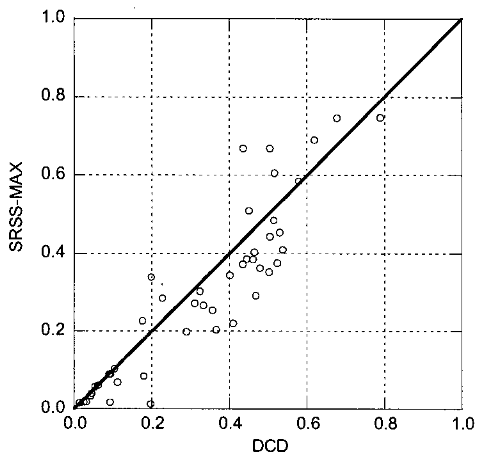
Figure 3.8-107(1) Comparison for SRSS Maximum Case (Load ID = 7241)



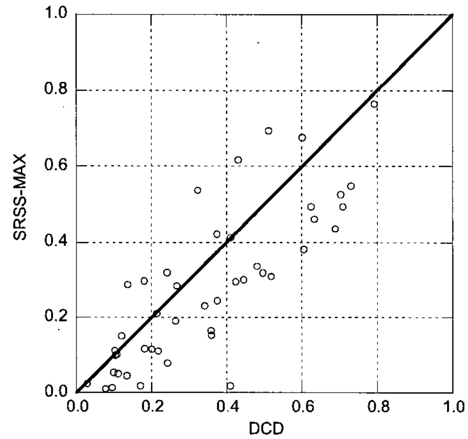
(a) Concrete



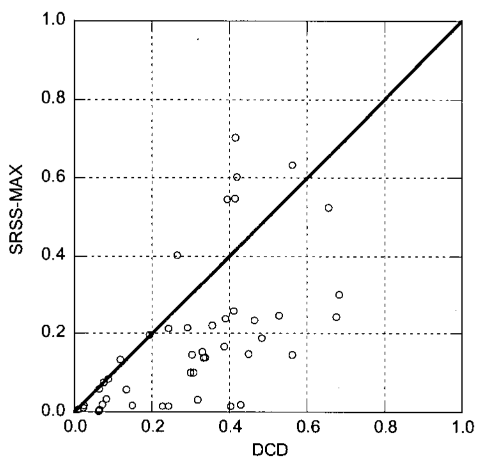
(b) Shear Tie



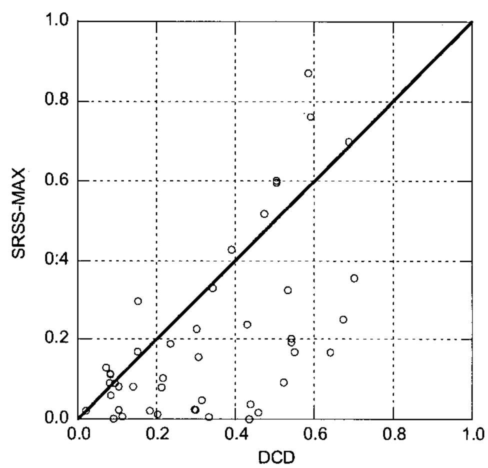
(c) Rebar 1



(d) Rebar 2

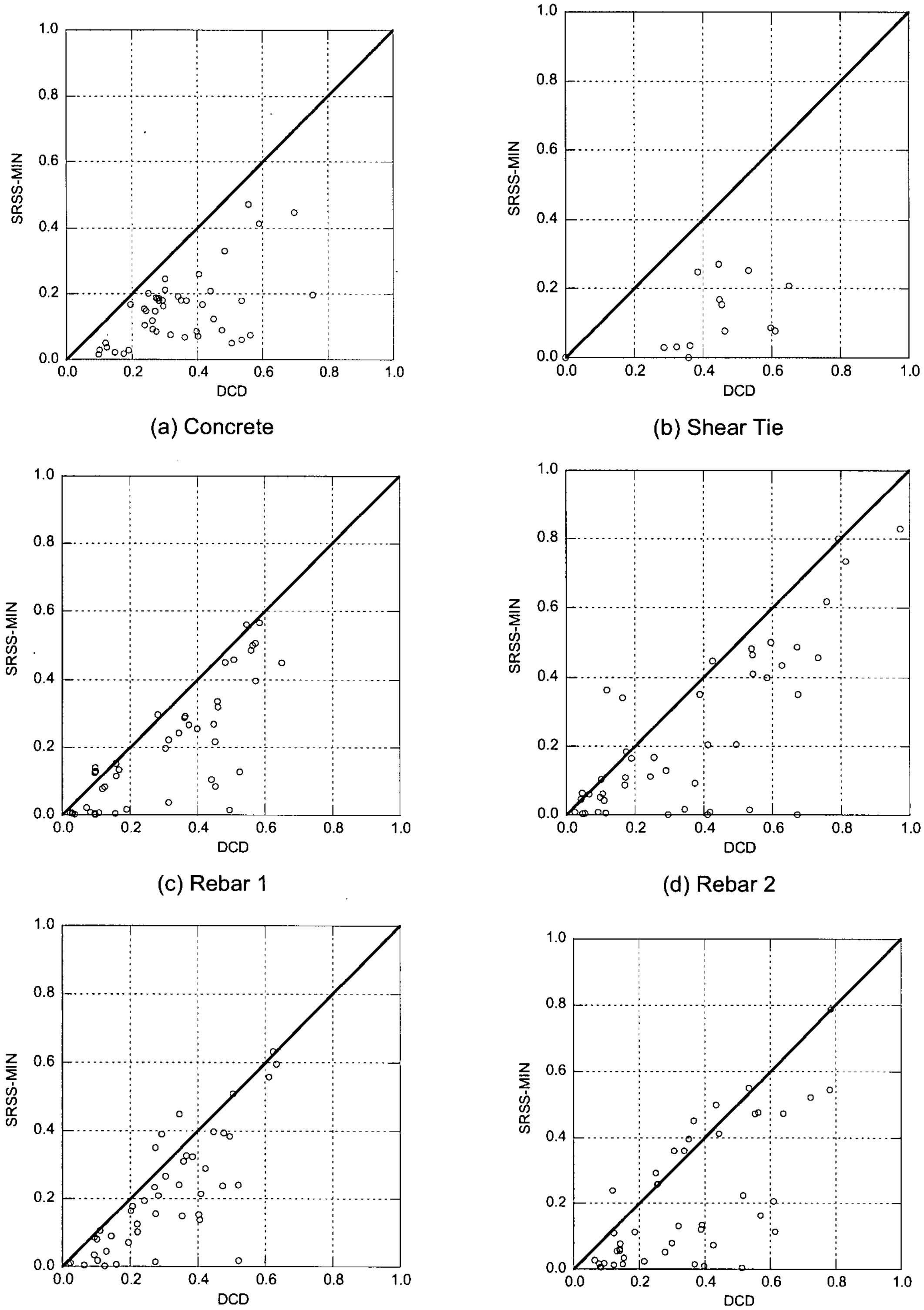


(e) Rebar 3



(f) Rebar 4

Figure 3.8-107(2) Comparison for SRSS Maximum Case (Load ID = 7441)



(a) Concrete

(b) Shear Tie

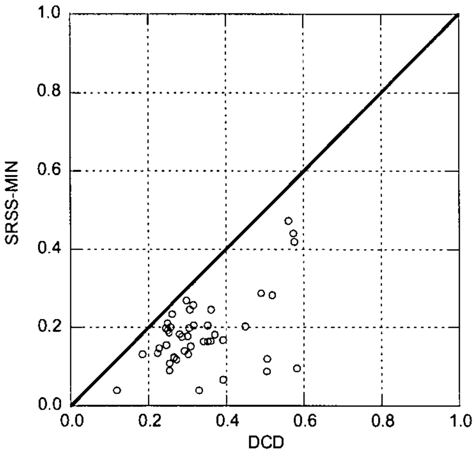
(c) Rebar 1

(d) Rebar 2

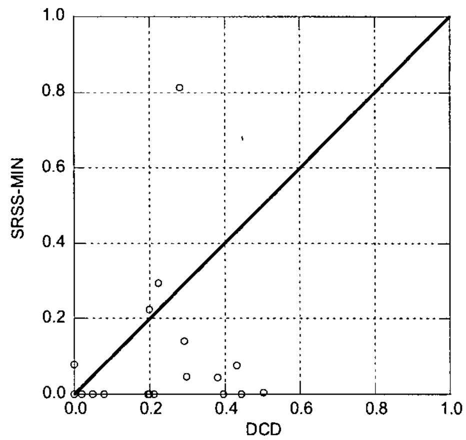
(e) Rebar 3

(f) Rebar 4

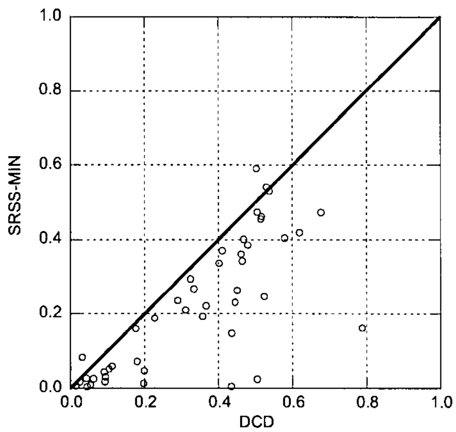
Figure 3.8-107(3) Comparison for SRSS Minimum Case (Load ID = 7241)



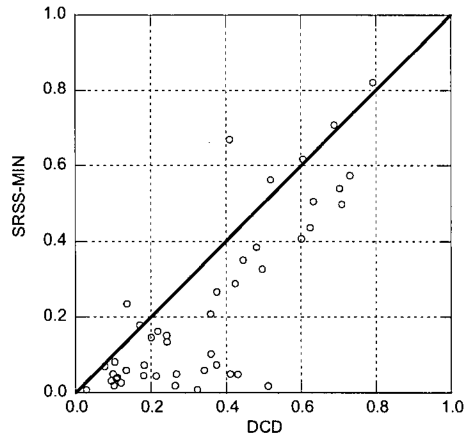
(a) Concrete



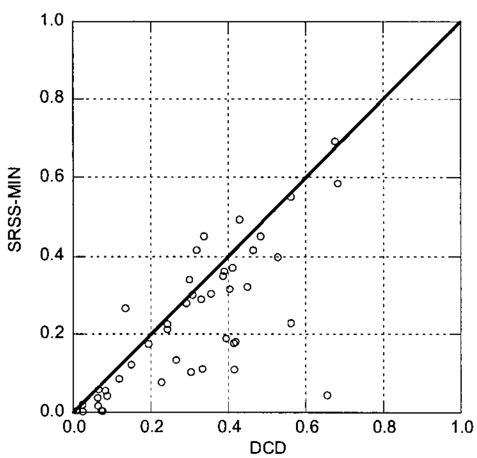
(b) Shear Tie



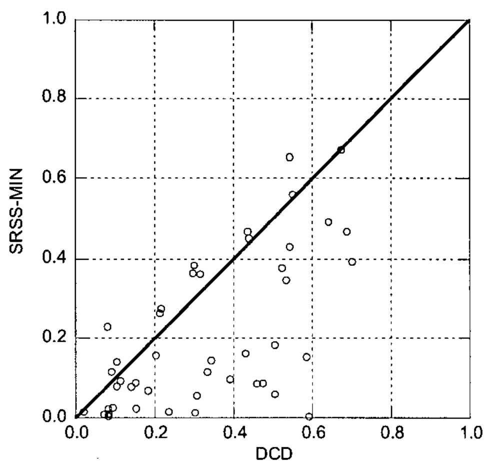
(c) Rebar 1



(d) Rebar 2

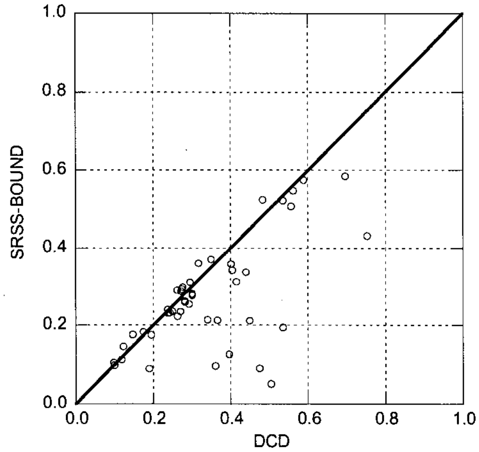


(e) Rebar 3

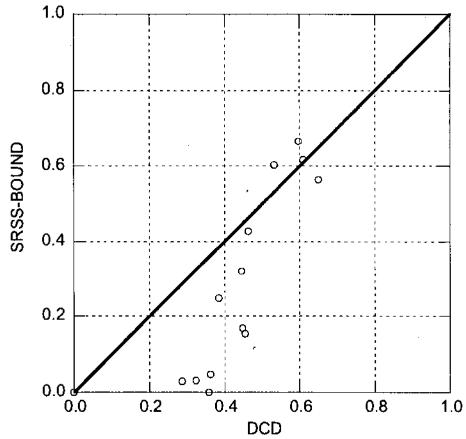


(f) Rebar 4

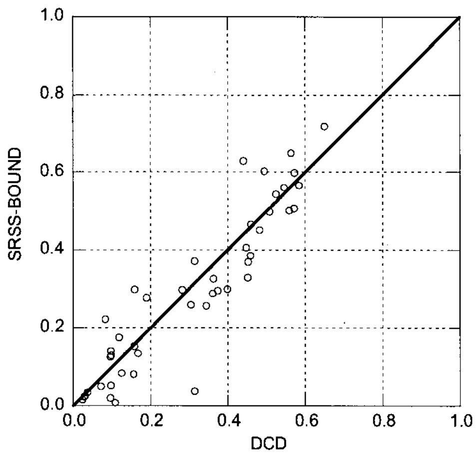
Figure 3.8-107(4) Comparison for SRSS Minimum Case (Load ID = 7441)



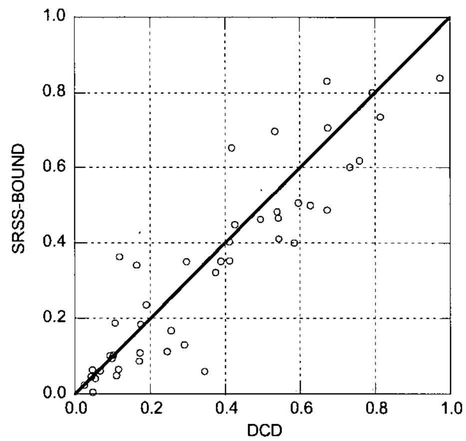
(a) Concrete



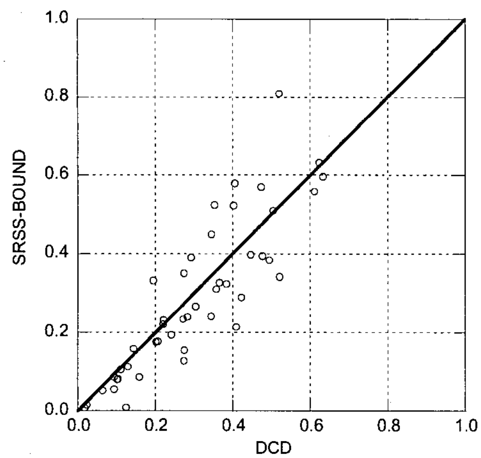
(b) Shear Tie



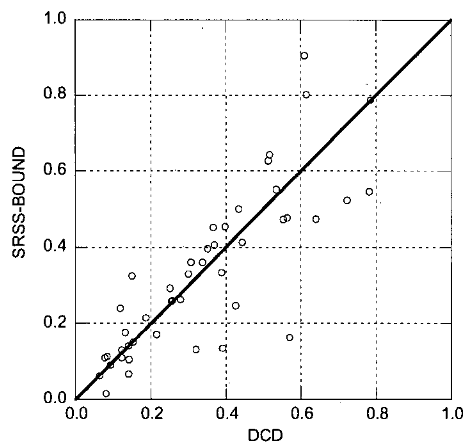
(c) Rebar 1



(d) Rebar 2



(e) Rebar 3



(f) Rebar 4

Figure 3.8-107(5) Comparison for SRSS Bound Case (Load ID = 7241)

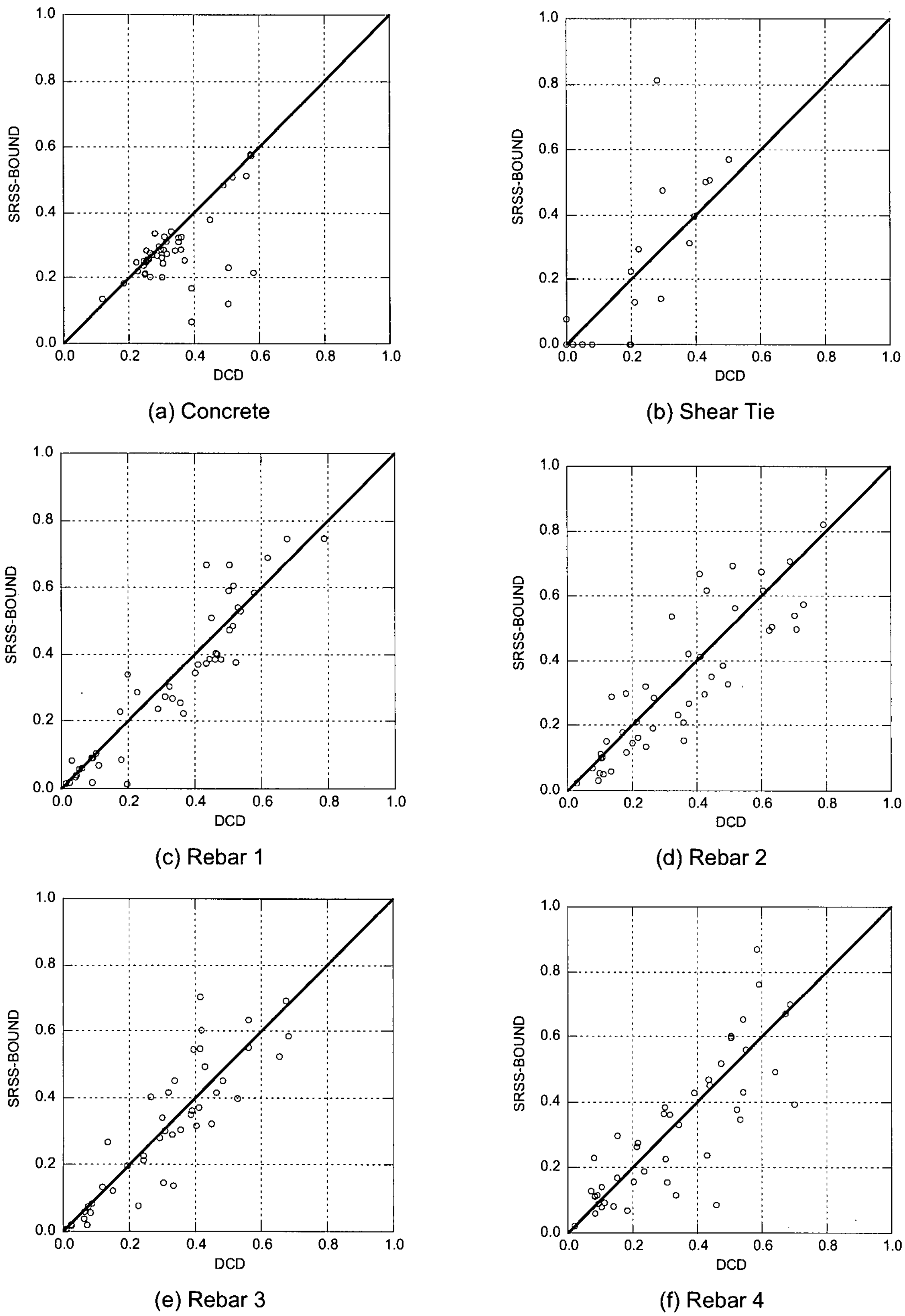
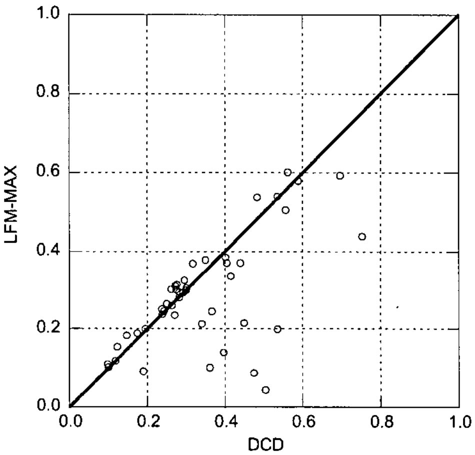
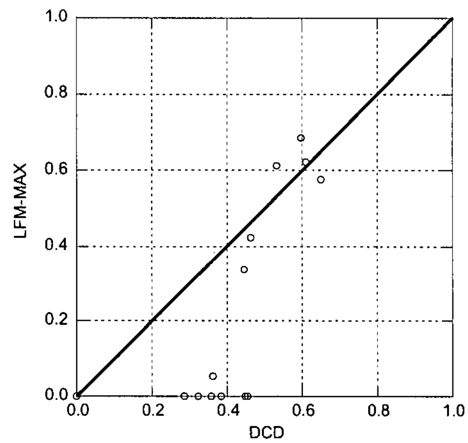


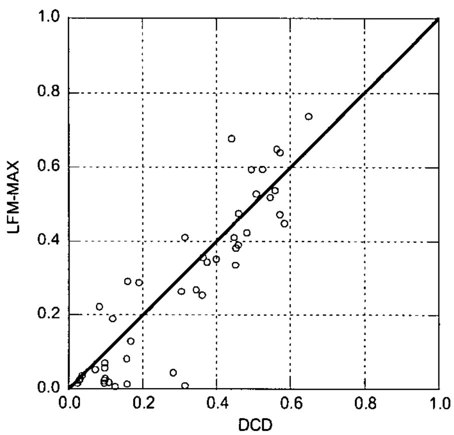
Figure 3.8-107(6) Comparison for SRSS Bound Case (Load ID = 7441)



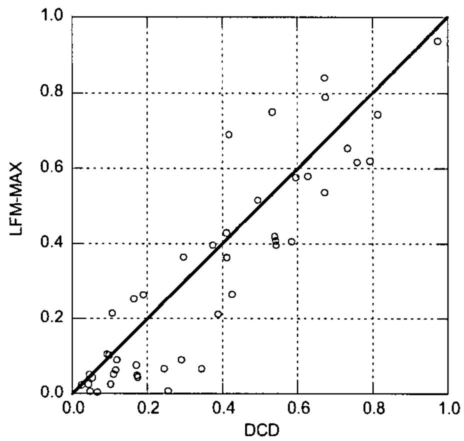
(a) Concrete



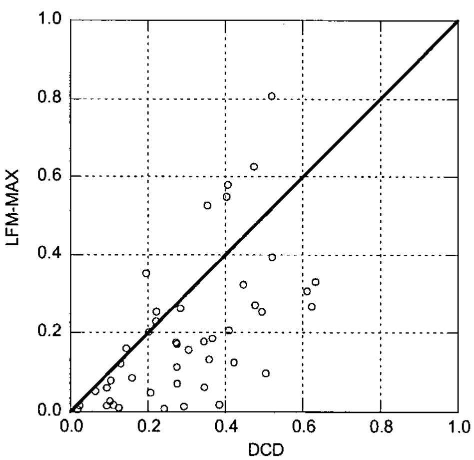
(b) Shear Tie



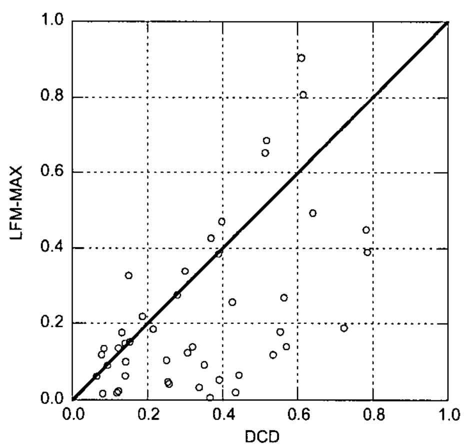
(c) Rebar 1



(d) Rebar 2



(e) Rebar 3



(f) Rebar 4

Figure 3.8-107(7) Comparison for Load Factored Method Maximum Case (Load ID = 7241)

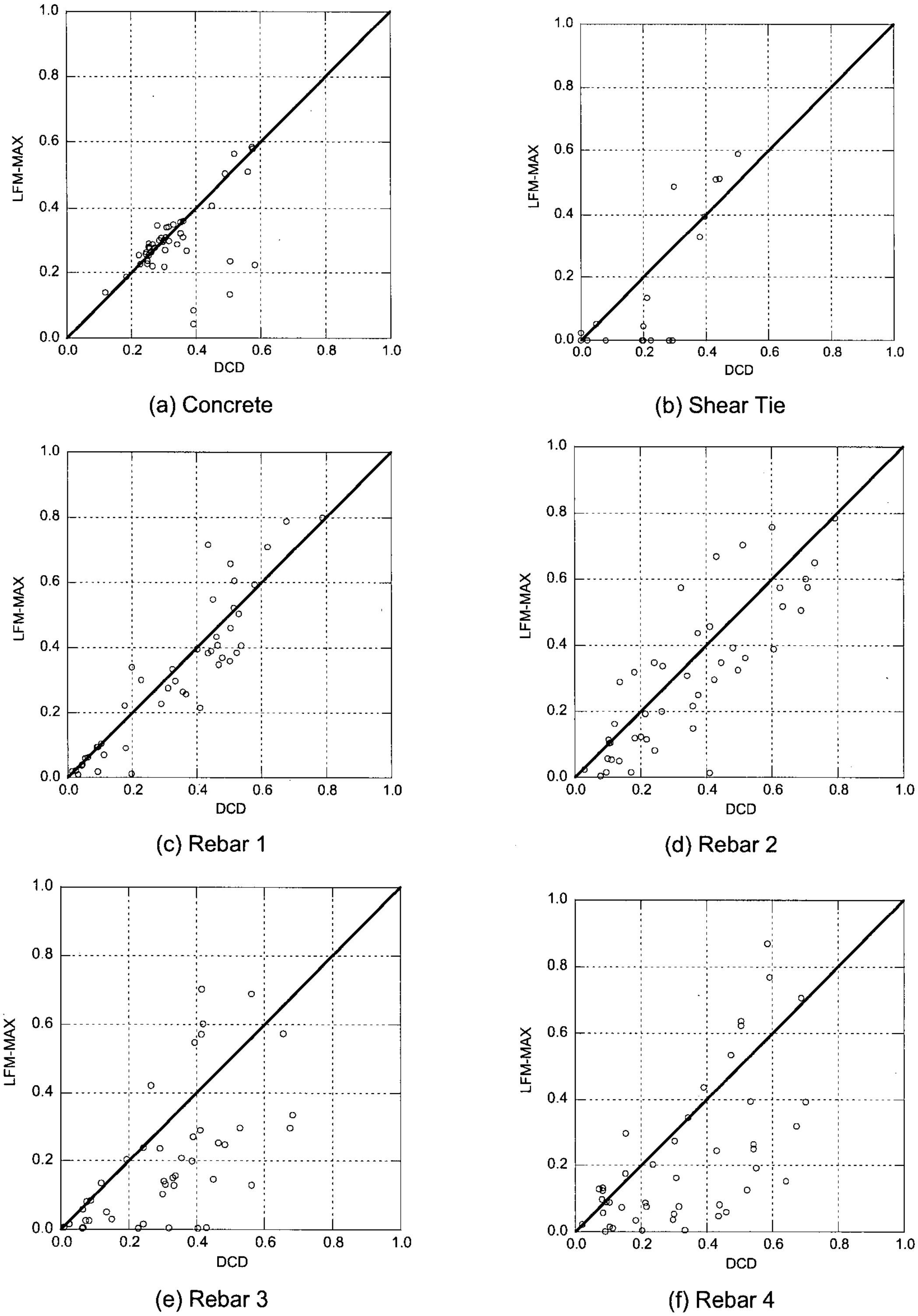
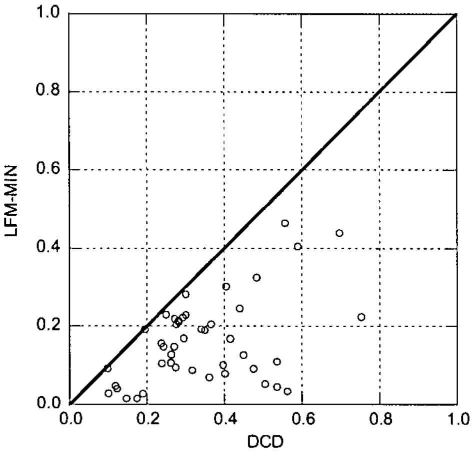
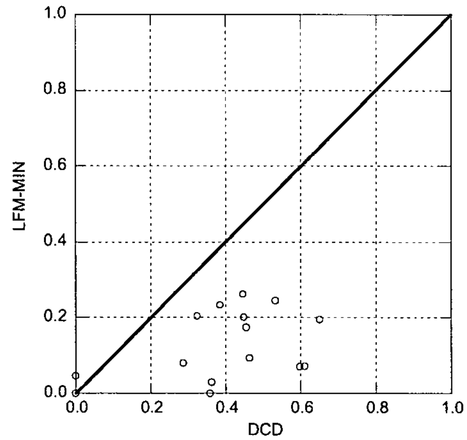


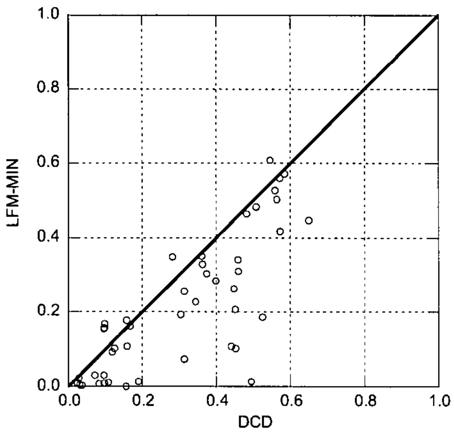
Figure 3.8-107(8) Comparison for Load Factored Method Maximum Case (Load ID = 7441)



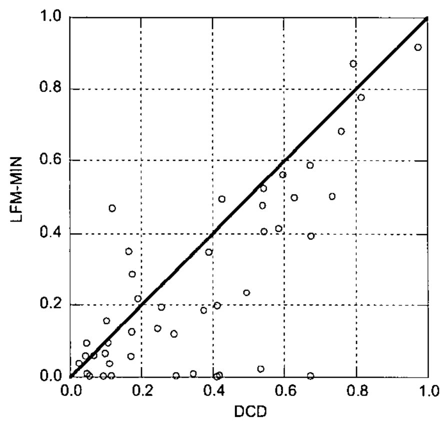
(a) Concrete



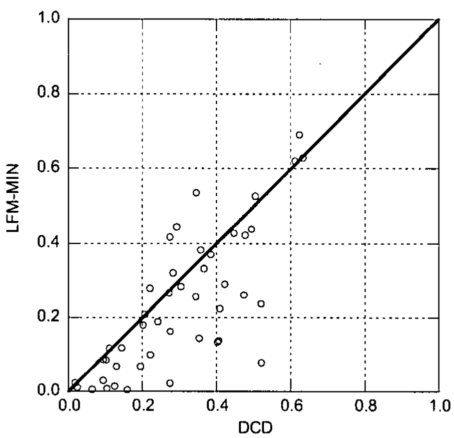
(b) Shear Tie



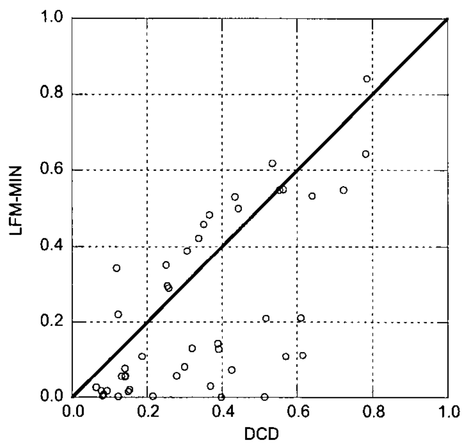
(c) Rebar 1



(d) Rebar 2

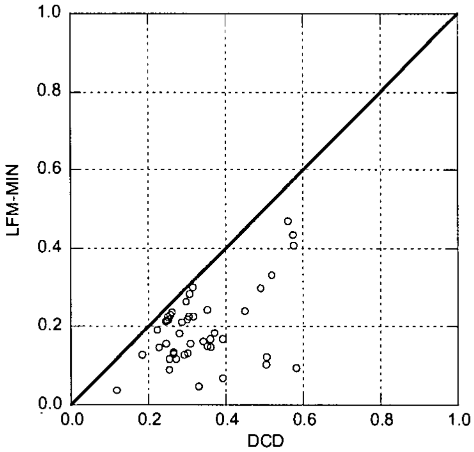


(e) Rebar 3

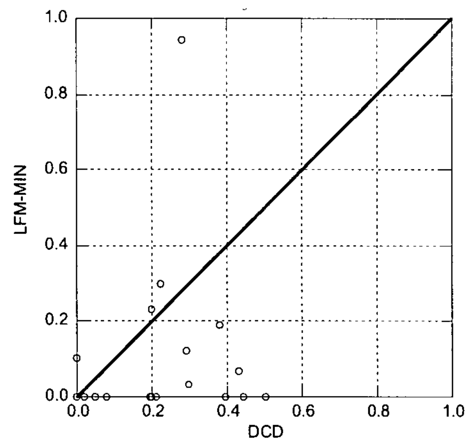


(f) Rebar 4

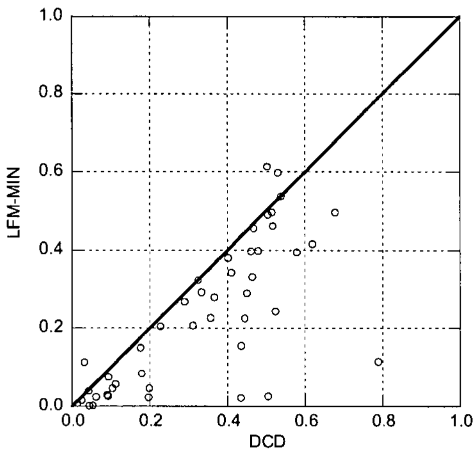
Figure 3.8-107(9) Comparison for Load Factored Method Minimum Case (Load ID = 7241)



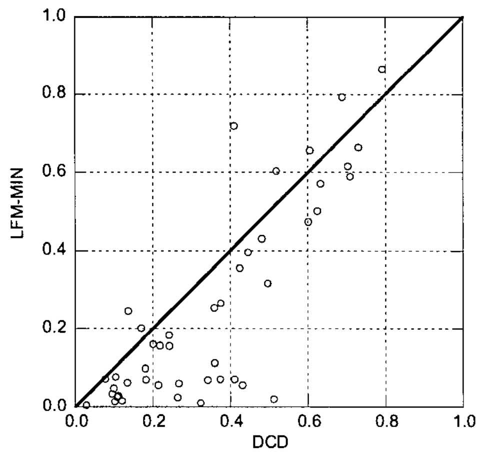
(a) Concrete



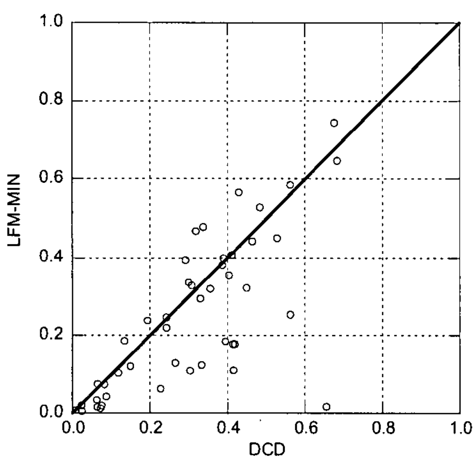
(b) Shear Tie



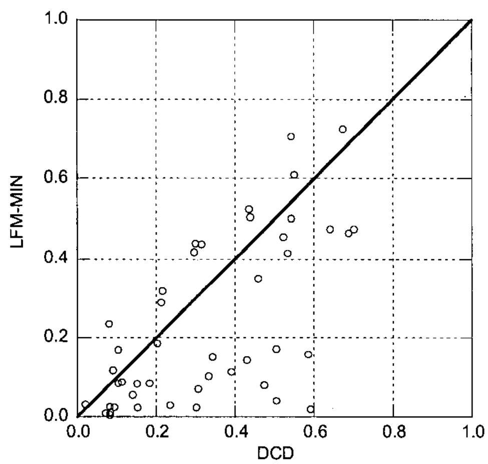
(c) Rebar 1



(d) Rebar 2



(e) Rebar 3



(f) Rebar 4

Figure 3.8-107(10) Comparison for Load Factored Method Minimum Case (Load ID = 7441)

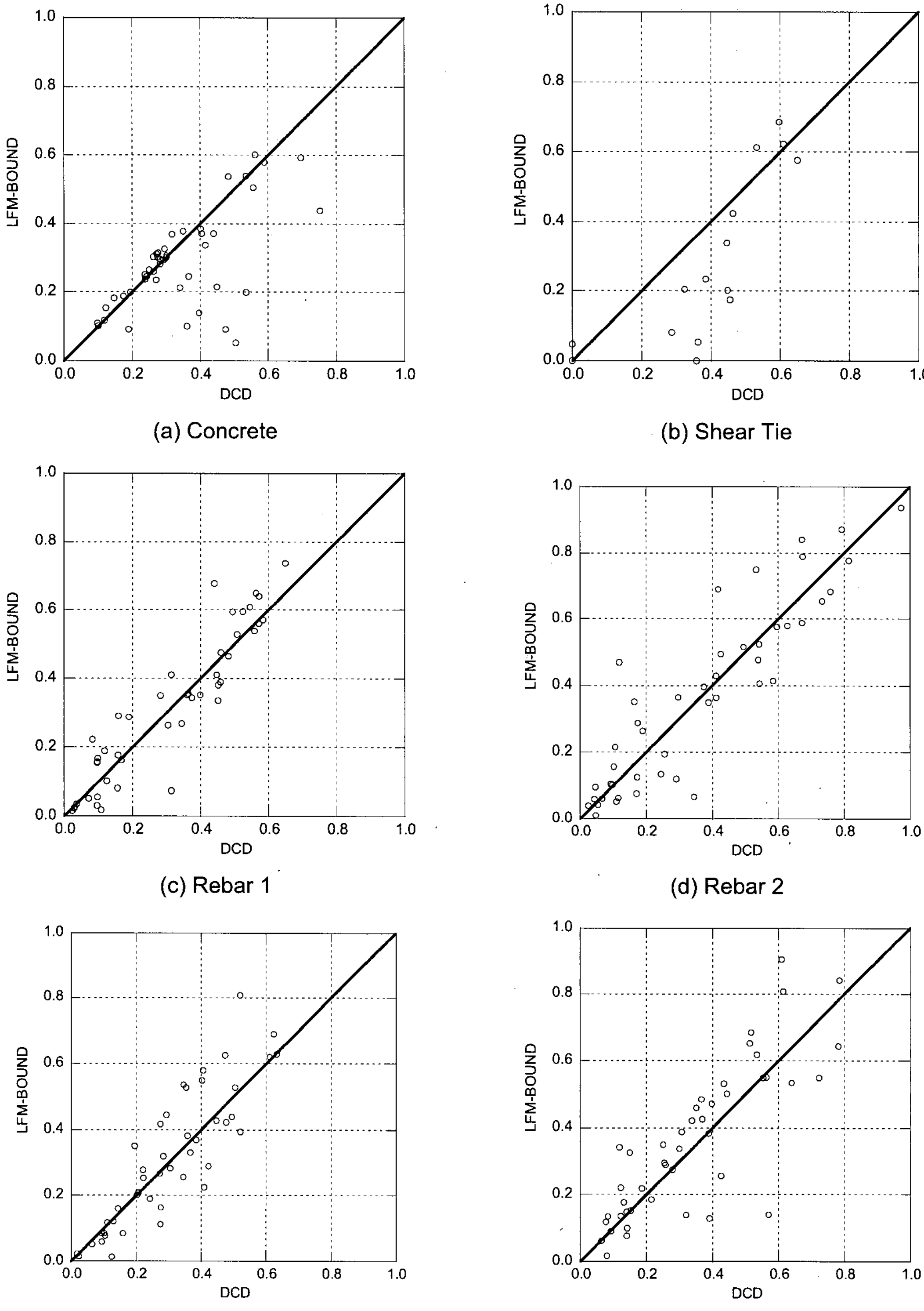
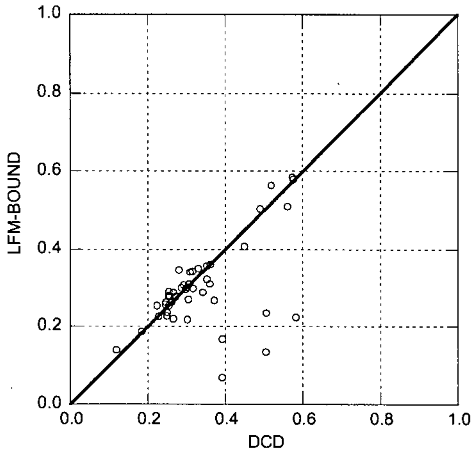
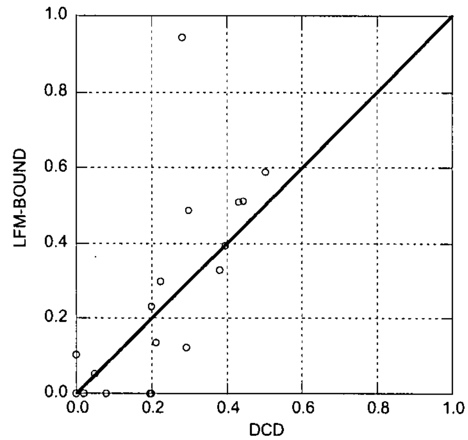


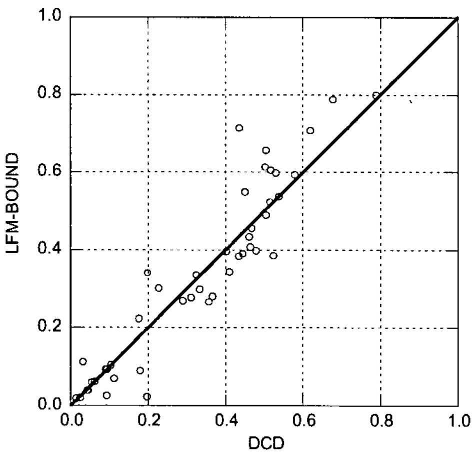
Figure 3.8-107(11) Comparison for Load Factored Method Bound Case (Load ID = 7241)



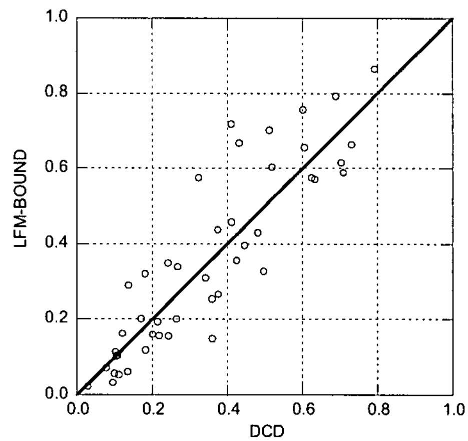
(a) Concrete



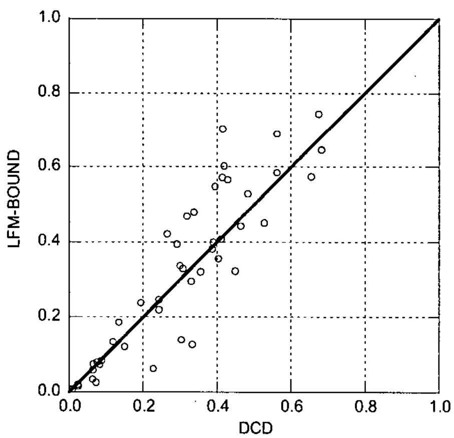
(b) Shear Tie



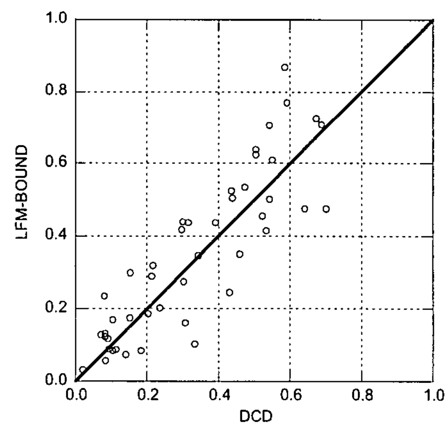
(c) Rebar 1



(d) Rebar 2



(e) Rebar 3



(f) Rebar 4

Figure 3.8-107(12) Comparison for Load Factored Method Bound Case (Load ID = 7441)

DCD Impact

No DCD change was made in response to this RAI Supplement.

NRC RAI 3.8-107, Supplement 2

Supplemental Request for Information on Responses to RAIs (E-mail from Chandu Patel Dated May 24, 2007)

(Comment on Response to NRC RAI 3.8-107, Supplement 1 Transmitted via MFN 06-416, Supplement 2 dated March 22, 2007 (Erroneously dated March 22, 2006 on MFN 06-416, Supplement 2))

(a) The staff reviewed the numerical data provided in the supplemental response to RAI 3.8-107, and did not reach the same general conclusion as the applicant, concerning the conservatism of the DCD results, compared to the SRSS and the RG 1.92 100/40/40 methods for combining responses from 3 directions of motion. The applicant is requested to address the following questions:

(1) From review of the Fot values in Tables 3.8-107(2) and 3.8-107(7), both listed as element 1824, it appears that the calculation for combined loading uses different values for the DCD method and for the SRSS/RG1.92 100/40/40 methods. Of particular note is Nx, listed as 4.096 in Table 3.8-107(2) and 0.946 in Table 3.8-107(7). Please explain this apparent discrepancy, which would tend to show the DCD method is conservative. If this is an error, re-calculate the combined loading results using the correct Fot loads, and provide the revised comparison results.

(2) All comparisons presented in Figures 3.8-107(1) thru (12) show that the predicted stress does not exceed the allowable stress limit, for all 3 methods of spatial combination. The data presented is based on a limited subset of locations and two (2) load combinations that include SSE. Please identify any locations and load combinations where the allowable stress limit is exceeded by any of the 3 spatial combination methods. Quantify the degree of exceedance.

(3) Figures 3.8-107(6)(b) and (10)(b) show one point where the SRSS and RG1.92 100/40/40 methods of spatial combination produce results significantly higher (factor of 2.5 to 3) than the DCD method. Please explain this large difference, and provide the technical basis for considering this large difference to be acceptable.

(4) The RG 1.92, Rev.2, acceptable procedure for implementation of the 100/40/40 rule was intended to produce the most conservative estimates of response components due to 3 directions of seismic loading. Since the calculated response components are absolute values and seismic response is oscillatory, both the positive and negative sign must be considered when combining with response components due to other loads. This is completely analogous to implementation of the SRSS combination method. Studies conducted by the staff demonstrated the conservatism of this approach, compared to SRSS. The staff requires clarification why, for combined loading cases, the DCD method of combination (ASCE 4-98 implementation of the100/40/40 rule) produces higher results than the RG 1.92 implementation procedure for the 100/40/40 rule at approximately 50% of the locations in the comparison tables.

(b) The staff also reviewed the revised validation report for SSDP-2D, provided in the applicant's initial response to RAI 3.8-107. Based on this review, the staff requests the following clarifications:
(1) Table 7 and Table 8 present the transverse shear analysis and code check for ASME 2004 and ACI349-01, respectively. Table 7 lists the stress units as MPa. Table 8 lists some units as MPa and some units as psi. Please revise these tables as appropriate, to identify the correct units.

(2) The results presented in Tables 7 and 8 each show excellent correlation with hand calculations. However, comparing the results in Table 7 to the results in Table 8, row 1 and row 5 show differences between the 2 codes, while the remaining rows show consistency. Please explain the basis for the differences in rows 1 and 5.

(3) The applicant is requested to provide a copy of the journal article utilized for the membrane section force calculation in Section 4.1 of the validation report. For Section 4.2 of the validation report, the applicant is requested to identify the source of the equations utilized for the axial force and bending moment calculation, and provide a copy of the applicable pages. In addition, explain whether the hand calculations solve the same set of equations utilized in the SSDP computer code, or whether the hand calculations use an independent approach. If the hand calculations use an independent approach, please describe the method used in the SSDP computer code.

(c) The staff noted that the calculation of FOT, used in demonstrating the combined loading comparisons, uses a unique thermal ratio for each individual internal force and moment resultant calculated by linear elastic thermal stress analysis using NASTRAN. For element 1824 used in the demonstration calculation, the thermal ratio varies as follows:

1.69 for Nx (1.981 goes to 3.348)
0.14 for Ny (-2.824 goes to -0.395)
1.0 for Nxy (0.082)
0.16 for Mx (-4.322 goes to -0.692)
0.29 for My (-7.438 goes to -2.157)
1.0 for Mxy (0.022)
-0.15 for Qx (-0.082 goes to 0.012)
0.24 for Qy (-1.354 goes to -0.325)

It is the staff's understanding that these ratios were obtained based on the results of two (2) ABAQUS/ANACAP analyses. The first was a linear elastic thermal stress analysis, and the second was a nonlinear thermal stress analysis that considered internal force and moment re-distribution due to concrete cracking and inelastic material behavior. The wide variation in the thermal ratios, and the significant reduction in the maximum elastically calculated results indicates that nonlinear behavior and re-distribution of internal forces and moments is very significant.

The staff has a concern that combining the nonlinear thermal stress analysis results with the elastically calculated results for other loads may not be appropriate. The correct approach, because of the significant nonlinear behavior evident in the ABAQUS/ANACAP thermal analysis, would be to apply all simultaneously occurring loads at the same time using the ABAQUS/ANACAP nonlinear model. In the presence of significant nonlinear behavior, linear superposition of results due to different applied load sets may lead to significant errors in the final combined loading response.

The staff requests the applicant to provide a detailed technical basis for the acceptability of its approach. Example comparisons for element 1824 and several other representative locations should be included in the response.

GEH Response

(a)

(1) The values of F_{ot} in Table 3.8-107(7) are in error. Table 3.8-107(11) is an update to Table 3.8-107(7) that shows the corrected values. Calculations were re-performed and Tables 3.8-107(12) and 3.8-107(13) are updates to Tables 3.8-107(9) and 3.8-107(10), respectively. Figures 3.8-107(13), 3.8-107(14) and 3.8-107(15) through 3.8-107(21) are updates to Figures 3.8-107(2), 3.8-107(4) and 3.8-107(6) through 3.8-107(12), respectively.

(2) To resolve the issue generically, the SRSS method permitted by RG 1.92 for combining earthquake spatial components is applied to the design, replacing the 100/40/40 method used previously. DCD Tier 2 Appendix 3G will be updated accordingly in Revision 5.

(3) Figures 3.8-107(6)(b) and 3.8-107(10)(b) are replaced by Figures 3.8-107(15)(b) and 3.8-107(19)(b), respectively, and no longer show the large differences noted. The large differences in these Figures was due to an error and has been corrected as discussed in the response to NRC RAI 3.8-107, Supplement 2, Item (a)(1).

(4) As an example, for the situation when the DCD method could predict higher results than the RG 1.92 method, Table 3.8-107(14) compares the stress in the vertical inside rebar calculated by the two methods in Element 1806 (RCCV Wetwell Bottom) for Load Combination 7241. The individual force/moment components are compared in Table 3.8-107(15). As for the tensile stress of the vertical inside rebar, the tensile axial force in the vertical direction (positive Ny in Table 3.8-107(15)) and the vertical bending moment which generates tensile force in the inside surface (positive My) are critical components. In the combined forces and moments for the RG 1.92 method, ${}_{MX}F_{LF}$ generates large positive My, but the vertical axial force is in the compressive direction. On the other hand, ${}_{MN}F_{LF}$ produces tensile axial force, but bending moment is small since the bending due to seismic loads is applied in the negative direction. Although the axial tensile force and bending moment in the critical combination of the DCD method are smaller than the maximum values between the ${}_{MX}F_{LF}$ and ${}_{MN}F_{LF}$ in the

RG 1.92 method, they are applied simultaneously and the resulting rebar tensile stress is larger than the stress from the RG 1.92 method.

(b)

(1) The psi units in MFN 06-416, Enclosure 2, Table 8 are incorrect and should be read as MPa. The values in the table are listed in SI units. The table is corrected and shown as Table 3.8-107(16).

(2) For row 1, different axial forces were considered in MFN 06-416, Enclosure 2, Tables 7 and 8. Since the calculations in these tables were performed independently, they did not need to use same input conditions.

As for row 5, the difference is caused by the differences of the concrete allowable stress calculation methods between ASME-2004 and ACI 349-01. As is shown in MFN 06-416, Enclosure 2, Figures 3 and 4, the calculation methods of the two codes are close but slightly different. For the case listed in row 5, the allowable stress is determined by the 2nd equation of v_{c21} in ASME-2004 (See MFN 06-416, Enclosure 2, Figure 3), and v_{c1} for the compressive axial force is controlling for ACI 349-01 (See MFN 06-416, Enclosure 2, Figure 4). Since the calculated concrete allowable stresses are slightly different, the resulting shear tie stresses, $\square_w$, are different.

(3) A copy of the ACI Journal article (NRC RAI 3.8-107, Supplement 2, Reference 1) utilized for the membrane section force calculation in MFN 06-416, Enclosure 2, Section 4.1 is attached as Attachment 3.8-107(2).

In MFN 06-416, Enclosure 2, Section 4.2, the source of the equations for axial force and bending moment calculations is based on AIJ Article 15 of NRC RAI 3.8-107, Supplement 2, Reference 2. A copy of this reference is attached as Attachment 3.8-107(3). These equations for axial force and bending moment are based on the theory of reinforced concrete design and are used in SSDP-2D, which complies with ASME Subsection CC and ACI-349. Please refer to Section 2 of "Two Dimensional Shimizu Section Design Program SSDP-2D Theoretical Description" in MFN 06-191, Supplement 6, Enclosure 2. This theory assumes:

1) Concrete and rebar are perfectly elastic.

2) Strain in reinforcement and concrete is directly proportional to the distance from the neutral axis.

3) The tensile strength of concrete is zero.

A textbook by Mr. S.S. Ray (NRC RAI 3.8-107, Supplement 2, Reference 3), provides similar equations and relevant pages are attached as Attachment 3.8-107(4).

The hand calculations solve the same set of equations utilized in the SSDP computer code.

(c) A demonstration analysis is performed to provide a basis for addressing this issue. The demonstration uses the detailed 3D ABAQUS/ANACAP finite element model. The first case considers a linear analysis for pressure loads combined with the nonlinear cracking analysis for thermal loads. For this case, the nonlinear cracking analysis is performed for the DBA thermal conditions at 72 hours. The DBA thermal conditions at 72 hours are considered for the demonstration because this condition maximizes the effect of thermal induced cracking with the deepest penetration of temperatures into the concrete walls. A separate linear analysis is then performed for application of the DBA pressure loads (no concrete cracking), and the stress results, both concrete compression and rebar tension, from these 2 analyses are added together. Thus, Case 1 provides the linear based stresses due to pressure combined with the nonlinear calculated stresses due to thermal. Case 2 then considers a true nonlinear analysis where both the pressure and temperature loads are applied simultaneously and incrementally with concrete cracking and stress redistribution. The maximum concrete compressive stresses and the maximum rebar tensile stresses are then compared between Case 1 and Case 2 for the section cuts used in calculating the thermal ratios from the previous analyses.

It is noted that this analysis, or any demonstration using linear based stresses for concrete, can only approximate the true situation, because the procedure used in the design contains an additional step that is not considered here. In the design procedure, the sections forces and moments are calculated for the load combinations and then the concrete section calculations are performed that eliminate any tensile stress in the concrete due to the linear analyses that is used to determine the section forces and moments. Thus, the linear analysis for pressure in the demonstration analysis can contain concrete tensile stresses that will not be present in the final design calculations. This final step in the design procedure may increase the concrete compressive stress slightly and will certainly increase the rebar tensile stress as the concrete tensile stress is eliminated and redistributed to the rebar. The design calculations force the rebars to take the tensile load that develops in the concrete from the linear analyses. Thus, a more meaningful comparison of linear and nonlinear results in this demonstration analysis is made at the stress level, rather than the section force level.

The results of this demonstration analysis are shown in the attached tables for the various section cuts at 72 hours after a LOCA event. The locations for the section cuts are provided in Figures 3.8-107(22), 3.8-107(23) and 3.8-107(24). Element 1824 in the NASTRAN design model corresponds to section "WW1" at the 180° azimuth. Table 3.8-107(17) is for the comparison between the peak Minimum Principal Stresses (concrete compressive stress) for Case 1 (linear pressure combined with cracked thermal) and Case 2 (nonlinear cracking for both thermal and pressure). The Ratio in the last column of the table is the ratio of Case 1 to Case 2, so that a number larger than 1 shows that the design procedure is conservative, i.e. the stress due to the combination of linear based pressure with that for cracked thermal is larger than the more accurate nonlinear cracking analysis of both pressure and thermal. It is seen that most locations are larger than 1 and some significantly larger than 1. Some locations are very near 1, within a few percent, and only 1 area, LW3, shows ratios less than 1. It is noted that this area has small stresses compared to the other areas, and it is outside of the primary containment boundary where internal pressures and elevated temperatures develop. At section

WW1-180° (NASTRAN element 1824), the ratio of concrete compressive stresses is 1.09.

Table 3.8-107(18) shows the results and comparisons for the peak rebar stress in these sections for the 2 Cases studied. Here ratios of Case 1 results divided by Case 2 results are provided for both hoop and vertical rebars on the various sections. Again, a ratio greater than 1 indicates that the combination with linear pressure and cracked thermal produces a larger stress than the nonlinear application of both loads. Here most locations are at or above a ratio of 1, but some locations show ratios less than 1. These locations are typically at locations of relatively low stress that are not controlling. The section design is based on the sections showing the largest stresses and for the worst-case load combinations. Again, because the linear pressure analysis allows tension in the concrete, the rebar tensile stress will be larger for the design calculations that disallow this concrete tension stress. At section WW1-180° (NASTRAN element 1824), the ratio of tensile stress in rebar for vertical bars is 1.88 and the ratio for hoop bars is 0.97.

In view of the results of this demonstration analysis, it can be concluded that combining the nonlinear thermal stress analysis results with the elastically calculated results for other loads is an adequate design approach.

Finally, it is noted that the ultimate pressure capacity calculations performed using the ABAQUS/ANACAP nonlinear modeling, both for fragility and Level C capacity in DCD Tier 2 Appendices 19B and 19C, show that the design for the RCCV, which is based on combinations of linear response for pressure and nonlinear response for thermal loading, has significant margins on the design basis loads. These calculations were performed as part of the PRA licensing requirements and explicitly address the question of how much margin or conservatism exists in the design of the primary containment system for the ESBWR. These analyses clearly demonstrate that the design procedures used in the concrete containment design for the ESBWR provide a conservative design with regards to failure under combined thermal and pressure loading.

It should be pointed out that errors have been identified in the thermal ratios that are used to account for the effects of thermal cracking in the linear thermal analyses as described in DCD Tier 2 Subsection 3.8.1.4.1.3. Evaluation of structural design adequacy will be repeated using the corrected thermal ratios and the summary results will be incorporated in Revision 5 of DCD Tier 2 Appendix 3G.

References:

1. "Analysis of Reinforced Concrete Membrane Subject to Tension and Shear", N. B. Duchon, ACI Journal, September 1972.

2. "AIJ Standard for Structural Calculation of Reinforced Concrete Structures", Architectural Institute of Japan, 1985.

3. "Reinforced Concrete Analysis and Design", S.S. Ray, Blackwell Science, 1995.

Table 3.8-107(11) Example of Combination

Element ID		Nx (MN/m)	Ny (MN/m)	Nxy (MN/m)	Mx (MNm/m)	My (MNm/m)	Mxy (MNm/m)	Qx (MN/m)	Qy (MN/m)
1824	F_{OT}	4.096	-3.197	0.085	0.092	2.428	0.043	-0.006	1.661
	F_{SRSS}	1.180	7.582	7.555	0.137	0.596	0.098	0.066	0.322
	F_{LF}	1.322	8.322	8.740	0.148	0.659	0.115	0.075	0.372
	$_{MX}F_{SRSS}$	5.276	-10.779	7.640	0.229	3.024	0.141	-0.072	1.983
	$_{MN}F_{SRSS}$	2.916	4.384	-7.470	-0.044	1.832	-0.055	0.060	1.339
	$_{MX}F_{LF}$	5.417	-11.519	8.825	0.241	3.087	0.158	-0.081	2.033
	$_{MN}F_{LF}$	2.774	5.124	-8.655	-0.056	1.769	-0.072	0.070	1.289

Table 3.8-107(12) Grouping of Comparison Results (SRSS Method)

SRSS Method	Group (SRSS-DCD)	Concrete				Main Bar				Shear Tie			
		Load ID		Sum	%	Load ID		Sum	%	Load ID		Sum	%
		7241	7441			7241	7441			7241	7441		
SRSS-MAX	□□> 0.1	0	0	0	0.0	17	20	37	10.3	0	0	0	0.0
	0.0 < □□≤ 0.1	13	13	26	28.9	27	31	58	16.1	3	4	7	7.8
	-0.1 < □□≤ 0.0	19	24	43	47.8	62	59	121	33.6	34	37	71	78.9
	□□≤ -0.1	13	8	21	23.3	74	70	144	40.0	8	4	12	13.3
	Total	*45*	*45*	*90*		*180*	*180*	*360*		*45*	*45*	*90*	
SRSS-MIN	□□> 0.1	0	0	0	0.0	4	2	6	1.7	0	1	1	1.1
	0.0 < □□≤ 0.1	0	0	0	0.0	24	18	42	11.7	0	0	0	0.0
	-0.1 < □□≤ 0.0	14	13	27	30.0	78	80	158	43.9	32	32	64	71.1
	□□≤ -0.1	31	32	63	70.0	74	80	154	42.8	13	12	25	27.8
	Total	*45*	*45*	*90*		*180*	*180*	*360*		*45*	*45*	*90*	
SRSS-BOUND	□□> 0.1	0	0	0	0.0	21	21	42	11.7	0	1	1	1.1
	0.0 < □□≤ 0.1	13	13	26	28.9	49	48	97	26.9	3	4	7	7.8
	-0.1 < □□≤ 0.0	19	24	43	47.8	82	80	162	45.0	34	36	70	77.8
	□□≤ -0.1	13	8	21	23.3	28	31	59	16.4	8	4	12	13.3
	Total	*45*	*45*	*90*		*180*	*180*	*360*		*45*	*45*	*90*	

Table 3.8-107(13) Grouping of Comparison Results (RG 1.92 Load Factored Method)

SRSS Method	Group (LFM-DCD)	Concrete				Main Bar				Shear Tie			
		Load ID		Sum	%	Load ID		Sum	%	Load ID		Sum	%
		7241	7441			7241	7441			7241	7441		
LFM-MAX	□□> 0.1	0	0	0	0.0	21	25	46	12.8	0	1	1	1.1
	0.0 < □□≤ 0.1	26	27	53	58.9	32	37	69	19.2	4	5	9	10.0
	-0.1 < □□≤ 0.0	9	11	20	22.2	61	58	119	33.1	33	35	68	75.6
	□□≤ -0.1	10	7	17	18.9	66	60	126	35.0	8	4	12	13.3
	Total	*45*	*45*	*90*		*180*	*180*	*360*		*45*	*45*	*90*	
LFM-MIN	□□> 0.1	0	0	0	0.0	11	19	30	8.3	1	1	2	2.2
	0.0 < □□≤ 0.1	0	0	0	0.0	36	21	57	15.8	0	1	1	1.1
	-0.1 < □□≤ 0.0	19	18	37	41.1	74	80	154	42.8	31	31	62	68.9
	□□≤ -0.1	26	27	53	58.9	59	60	119	33.1	13	12	25	27.8
	Total	*45*	*45*	*90*		*180*	*180*	*360*		*45*	*45*	*90*	
LFM-BOUND	□□> 0.1	0	0	0	0.0	31	42	73	20.3	1	2	3	3.3
	0.0 < □□≤ 0.1	26	27	53	58.9	65	56	121	33.6	4	5	9	10.0
	-0.1 < □□≤ 0.0	9	11	20	22.2	68	69	137	38.1	32	34	66	73.3
	□□≤ -0.1	10	7	17	18.9	16	13	29	8.1	8	4	12	13.3
	Total	*45*	*45*	*90*		*180*	*180*	*360*		*45*	*45*	*90*	

Table 3.8-107(14) Calculated Maximum Rebar Stress (Element 1806, Load Combination 7241)

Method	Combination of Seismic Forces	Stress in Vertical Inside Rebar (MPa)
RG 1.92 LFM	$_{MX}F_{LF}$	173.8
	$_{MN}F_{LF}$	207.1
DCD Method	No. 2 (See Table 3.8-107(5) in Supplement 1 response)	291.1

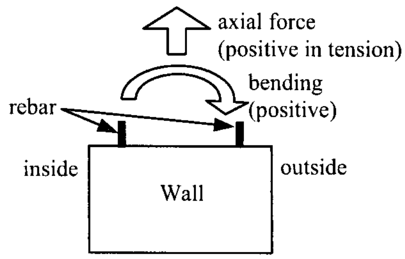


Table 3.8-107(15) Comparisons of Combined Forces and Moments between RG 1.92 and DCD Methods

			Nx (MN/m)	Ny (MN/m)	Nxy (MN/m)	Mx (MNm/m)	My (MNm/m)	Mxy (MNm/m)	Qx (MN/m)	Qy (MN/m)
Load excluding Seismic Loads		F_{OT}	1.163	-1.730	-0.354	0.142	2.517	0.077	0.036	1.424
RG 1.92 LFM	Seismic Loads	F_{LF}	2.508	6.676	7.316	0.381	2.649	0.147	0.028	0.971
	Combination (max)	$_{MX}F_{LF}$	3.671	**-8.406**	-7.670	0.523	**5.166**	0.224	0.064	2.395
	Combination (min)	$_{MN}F_{LF}$	-1.345	**4.946**	6.962	-0.239	**-0.132**	-0.070	0.008	0.453
DCD Method	Seismic Loads	$_{2}F_{DCD}$	-0.432	5.291	-6.750	-0.068	0.077	0.003	0.026	0.035
	Combination	$_{C2}F_{DCD}$	0.731	**3.561**	-7.104	0.074	**2.594**	0.080	0.062	1.459

Table 3.8-107(16) Comparisons between hand calculation and SSDP-2D for ACI 349-01 Transverse Shear (Revised Table 8 in SSDP-2D Validation Report)

fc'	34.5 MPa	5000 psi
h	2.0 m	78.74 in
d	1.5 m	59.06 in
fy	413.6 MPa	60000 psi
ρv	0.005	0.005

#	ρw'*1	ρw*1	Applied Force & Moment					Hand Calulation Results										SSDP-2D Results
								Concrete Allowable Stress							Shear Tie Stress			
								Nu=0			Compression			Tension				
			Vu	Nu	Mu	Mm	Vud/Mu	vc1	vc2	vc	vc1	vc2	vc	vc	vu	vs	σw	σw
			(MN/m)	(MN/m)	(MN-m/m)	(MN-m/m)		(MPa)	(MPa)	(MPa)	(MPa)	(MPa)	(MPa)	(MPa)	(MPa)	(MPa)	(MPa)	(MPa)
1	0.010	0.0133	1.751	0.000	0.267	0.267	1.00	1.16	1.71	**1.16**	3.19	1.71	1.71	0.98	1.37	0.22	43.5	43.4
2	0.010	0.0133	1.751	3.503	4.448	1.602	0.59	1.06	1.71	1.06	1.30	2.10	**1.30**	1.47	1.37	0.07	14.1	14.0
3	0.010	0.0133	1.751	0.175	8.896	8.754	0.30	0.99	1.71	0.99	1.00	1.73	**1.00**	1.00	1.37	0.38	75.7	75.5
4	0.010	0.0133	1.751	3.503	0.267	-2.579	1.00	1.16	1.71	1.16	0.69	2.10	**2.10**	1.47	1.37	0.00	0.0	0.0
5	0.010	0.0133	1.751	7.005	8.896	3.205	0.30	0.99	1.71	0.99	1.11	2.42	**1.11**	1.97	1.37	0.26	51.8	51.7
6	0.010	0.0133	1.751	-3.503	0.044	2.890	1.00	1.16	1.71	1.16	1.14	1.20	1.14	**0.48**	1.37	0.89	178.8	178.7
7	0.010	0.0133	1.751	-6.129	0.044	5.025	1.00	1.16	1.71	1.16	1.05	0.57	0.57	**0.11**	1.37	1.27	253.1	253.0
8	0.010	0.0133	3.152	0.175	8.896	8.754	0.53	1.05	1.71	1.05	1.05	1.73	**1.05**	1.00	2.47	1.42	284.4	284.3
9	0.010	0.0133	3.152	7.005	8.896	3.205	0.53	1.05	1.71	1.05	1.27	2.42	**1.27**	1.97	2.47	1.21	241.4	241.3
10	0.010	0.0133	3.152	-1.751	0.044	1.467	1.00	1.16	1.71	1.16	1.67	1.47	1.47	**0.73**	2.47	1.74	349.0	348.9

Note *1: "ρw'" is defined as As/(bh) and it is the input data for SSDP. "ρw" is defined as As/(bd) as specified in ACI 349.

Table 3.8-107(17) Summary of Concrete Compressive Stresses

Time = 72 hours   Stresses = Pa   SP1 = Minimum Principal Stress

Section	Location	Thermal Load Nonlinear	Mech. Load Linear	Case 1	Therm.+Mech. Nonlinear Case 2	Ratio Case1/Case2
		SP1	SP1	SP1	SP1	
DW1	0 deg	-1.85E+07	-3.41E+06	-2.19E+07	-2.20E+07	0.995
	45 deg	-2.01E+07	-3.41E+06	-2.35E+07	-2.30E+07	1.021
	90 deg	-1.79E+07	-3.39E+06	-2.13E+07	-2.20E+07	0.969
	180 deg	-1.80E+07	-3.47E+06	-2.15E+07	-2.18E+07	0.987
DW2	0 deg	-1.58E+07	-2.69E+06	-1.85E+07	-2.00E+07	0.923
	45 deg	-1.66E+07	-2.71E+06	-1.93E+07	-2.02E+07	0.957
	90 deg	-1.57E+07	-2.72E+06	-1.85E+07	-2.00E+07	0.923
	180 deg	-1.55E+07	-2.79E+06	-1.83E+07	-2.04E+07	0.900
DW3	0 deg	-1.54E+07	-6.42E+06	-2.18E+07	-1.89E+07	1.156
	45 deg	-1.54E+07	-6.46E+06	-2.18E+07	-1.94E+07	1.122
	90 deg	-1.55E+07	-6.58E+06	-2.21E+07	-1.96E+07	1.128
	180 deg	-1.60E+07	-6.60E+06	-2.26E+07	-1.90E+07	1.186
LW1	0 deg	-2.23E+06	-6.36E+06	-8.58E+06	-5.83E+06	1.473
	45 deg	-9.29E+05	-6.27E+06	-7.20E+06	-6.62E+06	1.088
	90 deg	-1.40E+06	-6.34E+06	-7.74E+06	-5.16E+06	1.502
	180 deg	-1.49E+06	-6.80E+06	-8.30E+06	-6.06E+06	1.369
LW2	0 deg	-4.46E+06	-1.70E+06	-6.17E+06	-5.48E+06	1.125
	45 deg	-3.46E+06	-1.90E+06	-5.36E+06	-4.95E+06	1.083
	90 deg	-3.92E+06	-1.80E+06	-5.72E+06	-5.07E+06	1.128
	180 deg	-3.87E+06	-1.98E+06	-5.85E+06	-5.32E+06	1.100
LW3	0 deg	-3.49E+06	-1.79E+06	-5.28E+06	-8.93E+06	0.592
	45 deg	-2.77E+06	-2.16E+06	-4.93E+06	-7.54E+06	0.654
	90 deg	-3.88E+06	-1.85E+06	-5.73E+06	-7.95E+06	0.720
	180 deg	-4.15E+06	-2.08E+06	-6.24E+06	-9.51E+06	0.656
WW1	0 deg	-2.14E+07	-1.08E+06	-2.25E+07	-1.89E+07	1.190
	45 deg	-2.14E+07	-1.44E+06	-2.28E+07	-1.91E+07	1.193
	90 deg	-1.92E+07	-1.45E+06	-2.06E+07	-1.71E+07	1.203
	180 deg	-2.03E+07	-1.37E+06	-2.16E+07	-1.98E+07	1.091
WW2	0 deg	-1.50E+07	-8.35E+05	-1.59E+07	-1.61E+07	0.986
	45 deg	-1.25E+07	-9.53E+05	-1.34E+07	-1.36E+07	0.990
	90 deg	-1.30E+07	-1.08E+06	-1.41E+07	-1.42E+07	0.992
	180 deg	-1.41E+07	-1.14E+06	-1.53E+07	-1.61E+07	0.947
WW3	0 deg	-1.13E+07	-2.36E+06	-1.37E+07	-1.08E+07	1.273
	45 deg	-8.11E+06	-1.67E+06	-9.78E+06	-7.24E+06	1.350
	90 deg	-8.32E+06	-2.12E+06	-1.04E+07	-7.63E+06	1.370
	180 deg	-8.25E+06	-8.31E+05	-9.09E+06	-8.34E+06	1.089
UW1	0 deg	-1.75E+07	-5.72E+05	-1.80E+07	-1.71E+07	1.056
	45 deg	-1.70E+07	-4.72E+05	-1.75E+07	-1.67E+07	1.051
	90 deg	-1.29E+07	-6.88E+05	-1.36E+07	-1.21E+07	1.118
	180 deg	-1.73E+07	-4.85E+05	-1.78E+07	-1.82E+07	0.974
UW2	0 deg	-1.62E+07	-2.03E+06	-1.82E+07	-1.29E+07	1.418
	45 deg	-1.05E+07	-1.70E+06	-1.22E+07	-8.48E+06	1.435
	90 deg	-1.31E+07	-1.75E+06	-1.49E+07	-1.04E+07	1.435
	180 deg	-1.19E+07	-2.45E+06	-1.43E+07	-1.01E+07	1.421
UW3	0 deg	-2.01E+07	-4.02E+05	-2.05E+07	-2.01E+07	1.019
	45 deg	-1.74E+07	-3.60E+05	-1.78E+07	-1.72E+07	1.033
	90 deg	-1.82E+07	-7.08E+05	-1.89E+07	-1.82E+07	1.039
	180 deg	-1.56E+07	-3.97E+05	-1.60E+07	-1.59E+07	1.005

Table 3.8-107(17) Summary of Concrete Compressive Stresses (Cont'd)

Time = 72 hours   Stresses = Pa   SP1 = Minimum Principal Stress

		Thermal Load Nonlinear	Mech. Load Linear	Case 1	Therm.+Mech. Nonlinear Case 2	Ratio Case1/Case2
Section	Location	SP1	SP1	SP1	SP1	
SP1	0 deg	-1.81E+07	-8.44E+05	-1.90E+07	-1.42E+07	1.336
	45 deg	-1.79E+07	-8.77E+05	-1.88E+07	-1.56E+07	1.199
	90 deg	-1.69E+07	-8.12E+05	-1.77E+07	-1.35E+07	1.309
	180 deg	-1.82E+07	-8.38E+05	-1.90E+07	-1.53E+07	1.244
SP2	0 deg	-1.50E+07	-1.85E+06	-1.69E+07	-1.73E+07	0.975
	45 deg	-1.61E+07	-1.93E+06	-1.80E+07	-1.85E+07	0.972
	90 deg	-1.53E+07	-1.82E+06	-1.71E+07	-1.73E+07	0.986
	180 deg	-1.51E+07	-1.89E+06	-1.70E+07	-1.76E+07	0.962
SP3	0 deg	-2.09E+07	-4.57E+06	-2.55E+07	-1.50E+07	1.701
	45 deg	-2.11E+07	-4.91E+06	-2.60E+07	-1.56E+07	1.666
	90 deg	-2.12E+07	-4.62E+06	-2.59E+07	-1.54E+07	1.680
	180 deg	-2.10E+07	-4.68E+06	-2.57E+07	-1.46E+07	1.760
TS1	0 deg	-1.41E+07	-1.04E+06	-1.51E+07	-1.31E+07	1.151
	45 deg	-9.52E+06	-1.00E+06	-1.05E+07	-8.02E+06	1.312
	90 deg	-9.89E+06	-1.56E+06	-1.15E+07	-9.89E+06	1.157
	180 deg	-1.32E+07	-1.01E+06	-1.42E+07	-9.71E+06	1.467
TS2	0 deg	-1.33E+07	-5.50E+05	-1.38E+07	-1.33E+07	1.037
	45 deg	-1.05E+07	-7.14E+05	-1.12E+07	-1.05E+07	1.073
	90 deg	-1.12E+07	-7.07E+05	-1.19E+07	-1.15E+07	1.033
	180 deg	-1.19E+07	-5.86E+05	-1.25E+07	-1.12E+07	1.113
TS3	0 deg	-1.52E+07	-9.51E+05	-1.62E+07	-1.60E+07	1.011
	45 deg	-1.40E+07	-7.82E+05	-1.48E+07	-1.42E+07	1.037
	90 deg	-1.26E+07	-1.63E+06	-1.43E+07	-1.35E+07	1.056
	180 deg	-1.35E+07	-1.48E+06	-1.50E+07	-1.43E+07	1.050

Table 3.8-107(18) Summary of Rebar Tensile Stress

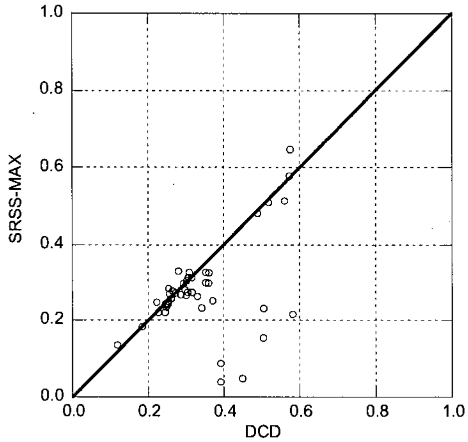
Time = 72 hours Stresses = MPa

		Thermal Load Nonlinear		Mechanical Load Linear		Case 1		Therm.+Mech. Loads Nonlinear Case 2		Ratio Case1/Case2	
Section	Location	Vert.	Hoop	Vert.	Hoop	Vert.	Hoop	Vert.	Hoop	Vert.	Hoop
DW1	0 deg	146.2	89.7	-15.6	7.2	130.6	97.0	118.7	116.3	1.10	0.83
	45 deg	185.0	124.4	-15.5	7.2	169.4	131.6	116.9	119.3	1.45	1.10
	90 deg	148.5	86.3	-15.3	6.9	133.3	93.2	94.5	113.6	1.41	0.82
	180 deg	155.4	71.0	-17.0	7.2	138.4	78.2	114.8	107.9	1.21	0.72
DW2	0 deg	178.2	110.1	-15.9	8.6	162.3	118.7	157.9	135.6	1.03	0.88
	45 deg	192.8	139.6	-16.2	8.5	176.6	148.1	135.7	143.0	1.30	1.04
	90 deg	179.3	110.5	-16.1	8.3	163.1	118.8	137.3	143.9	1.19	0.83
	180 deg	187.9	120.9	-17.0	8.6	170.9	129.5	151.3	136.6	1.13	0.95
DW3	0 deg	102.0	80.5	-2.8	0.7	99.2	81.2	15.3	91.3	6.49	0.89
	45 deg	93.9	91.3	-2.8	0.6	91.1	91.9	4.3	101.2	21.38	0.91
	90 deg	108.9	94.6	-2.9	0.4	106.0	94.9	11.4	112.9	9.31	0.84
	180 deg	105.9	84.6	-2.9	0.7	103.0	85.3	9.2	98.2	11.16	0.87
LW1	0 deg	5.0	8.0	-0.8	4.6	4.2	12.6	-6.1	16.2	-0.69	0.78
	45 deg	5.2	7.9	-4.9	5.3	0.2	13.2	-2.2	17.0	-0.10	0.78
	90 deg	5.8	9.5	-0.3	4.7	5.4	14.2	-3.1	20.8	-1.75	0.68
	180 deg	4.9	8.8	-2.4	5.1	2.5	13.9	-5.1	21.5	-0.49	0.65
LW2	0 deg	14.2	56.6	-8.7	2.6	5.5	59.1	3.2	33.7	1.72	1.75
	45 deg	12.8	13.1	-10.1	3.5	2.7	16.6	1.9	22.4	1.45	0.74
	90 deg	14.2	61.7	-9.2	2.7	5.1	64.4	3.0	97.0	1.71	0.66
	180 deg	15.1	15.9	-10.2	3.0	4.9	18.9	-0.5	94.9	-9.35	0.20
LW3	0 deg	23.2	110.7	-7.6	2.7	15.6	113.4	7.4	94.7	2.10	1.20
	45 deg	8.3	138.9	-8.5	3.2	-0.3	142.1	3.6	82.0	-0.08	1.73
	90 deg	47.5	99.1	-8.2	2.5	39.3	101.6	6.9	90.3	5.66	1.12
	180 deg	34.0	125.7	-9.4	2.8	24.6	128.4	7.2	106.8	3.40	1.20
WW1	0 deg	108.6	90.8	0.1	3.8	108.7	94.5	62.0	103.0	1.75	0.92
	45 deg	137.5	103.5	-0.5	4.2	136.9	107.7	122.3	131.4	1.12	0.82
	90 deg	122.7	97.8	-0.8	3.4	121.9	101.1	72.5	103.0	1.68	0.98
	180 deg	128.5	93.3	-2.2	4.0	126.3	97.3	67.4	100.5	1.88	0.97
WW2	0 deg	13.9	116.4	0.1	7.7	14.0	124.1	20.2	126.6	0.69	0.98
	45 deg	11.8	111.3	-0.2	8.2	11.6	119.5	45.8	136.7	0.25	0.87
	90 deg	18.7	105.9	-1.4	7.0	17.3	112.8	17.0	132.3	1.02	0.85
	180 deg	13.7	111.6	-2.3	7.4	11.5	118.9	16.1	124.5	0.71	0.95
WW3	0 deg	156.5	138.5	0.1	6.8	156.6	145.3	121.1	157.3	1.29	0.92
	45 deg	222.7	178.5	-0.7	7.2	222.1	185.7	185.5	189.3	1.20	0.98
	90 deg	176.0	156.2	-1.0	5.8	175.0	162.0	147.0	166.4	1.19	0.97
	180 deg	117.9	133.8	-0.2	5.1	117.7	138.9	37.6	151.2	3.13	0.92

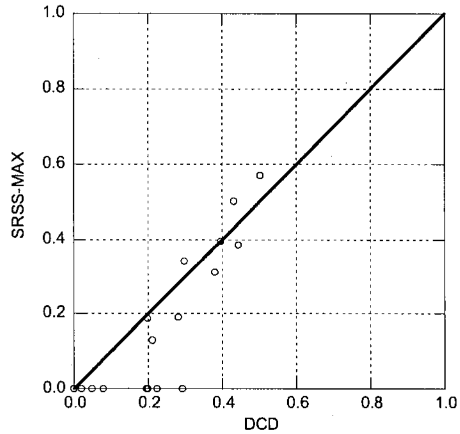
Table 3.8-107(18) Summary of Rebar Tensile Stress (Cont'd)

Time = 72 hours Stresses = MPa

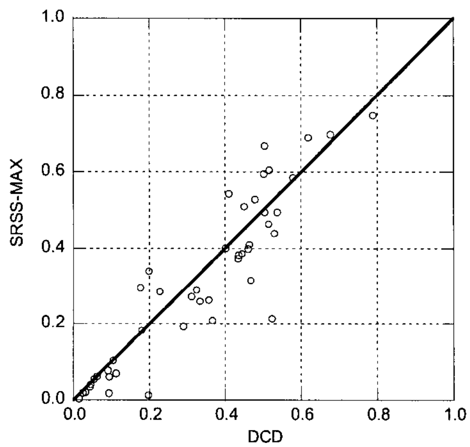
		Thermal Load Nonlinear		Mechanical Load Linear		Case 1		Therm.+Mech. Loads Nonlinear Case 2		Ratio Case1/Case2	
Section	Location	Vert.,R, X	Hoop or Y	Vert.,R, X	Hoop or Y	Vert.,R, X	Hoop or Y	Vert.,R, X	Hoop or Y	Vert.,R, X	Hoop or Y
UW1	0 deg	185.7	178.1	4.2	6.2	189.9	184.3	206.9	175.0	0.92	1.05
	45 deg	237.9	185.8	2.2	6.5	240.1	192.2	233.7	200.8	1.03	0.96
	90 deg	226.5	177.0	1.1	5.6	227.6	182.6	205.0	189.7	1.11	0.96
	180 deg	192.7	117.8	0.5	5.2	193.2	122.9	182.9	129.9	1.06	0.95
UW2	0 deg	3.7	119.2	10.6	1.3	14.3	120.5	-6.5	129.0	-2.20	0.93
	45 deg	87.6	157.9	10.2	0.8	97.8	158.7	83.0	178.6	1.18	0.89
	90 deg	95.5	160.0	6.5	1.5	102.0	161.5	83.9	165.7	1.22	0.98
	180 deg	-9.1	62.4	8.6	2.6	-0.5	65.1	15.1	70.8	-0.04	0.92
UW3	0 deg	159.8	158.2	3.3	4.7	163.1	162.9	163.6	168.7	1.00	0.97
	45 deg	173.0	169.2	2.7	4.7	175.7	173.8	197.1	190.6	0.89	0.91
	90 deg	162.9	182.3	1.6	4.7	164.5	187.0	176.0	196.9	0.93	0.95
	180 deg	132.0	98.5	1.3	4.7	133.2	103.2	125.3	105.0	1.06	0.98
SP1	0 deg	106.3	87.6	7.1	2.9	113.5	90.5	95.5	115.2	1.19	0.79
	45 deg	99.6	127.8	6.7	3.2	106.3	130.9	83.7	81.4	1.27	1.61
(R,H)	90 deg	89.8	87.1	7.7	2.6	97.5	89.7	71.4	134.5	1.37	0.67
	180 deg	145.6	134.5	7.7	3.0	153.3	137.5	105.3	117.7	1.46	1.17
SP2	0 deg	19.4	60.9	15.9	5.4	35.4	66.2	116.5	103.3	0.30	0.64
	45 deg	18.3	119.2	15.6	5.8	33.9	125.0	83.2	125.5	0.41	1.00
(R,H)	90 deg	32.2	120.2	16.5	4.9	48.7	125.1	123.8	103.4	0.39	1.21
	180 deg	18.7	131.5	16.1	5.5	34.8	137.0	126.2	86.6	0.28	1.58
SP3	0 deg	13.4	116.8	9.1	7.8	22.6	124.6	3.8	101.3	5.94	1.23
	45 deg	8.2	128.3	8.7	7.8	16.9	136.1	0.7	128.4	24.29	1.06
(R,H)	90 deg	10.5	114.8	9.3	7.4	19.8	122.2	10.4	104.6	1.90	1.17
	180 deg	14.2	48.4	9.5	8.0	23.7	56.3	7.0	92.9	3.41	0.61
TS1	0 deg	46.1	19.7	11.7	4.0	57.8	23.7	7.1	91.1	8.13	0.26
	45 deg	0.7	16.7	5.2	6.7	5.9	23.4	12.3	19.4	0.48	1.21
(XY)	90 deg	31.5	67.1	1.9	14.9	33.4	82.0	64.9	41.3	0.51	1.99
	180 deg	84.2	86.9	11.0	6.1	95.2	93.0	58.0	128.9	1.64	0.72
TS2	0 deg	51.5	67.4	3.1	6.5	54.5	73.9	83.4	87.1	0.65	0.85
	45 deg	30.7	25.2	1.4	7.4	32.1	32.6	22.8	41.1	1.40	0.79
(XY)	90 deg	0.4	36.5	2.8	4.6	3.2	41.1	16.4	39.7	0.20	1.04
	180 deg	13.4	94.7	3.0	8.5	16.3	103.2	106.2	110.3	0.15	0.94
TS3	0 deg	-6.9	162.8	-0.1	13.2	-7.0	176.0	-10.3	207.5	0.67	0.85
	45 deg	108.2	114.4	0.7	6.9	108.9	121.3	102.0	105.0	1.07	1.16
(XY)	90 deg	102.1	-6.2	0.5	2.5	102.6	-3.7	138.1	27.0	0.74	-0.14
	180 deg	-9.2	137.4	-0.4	16.2	-9.6	153.6	-10.4	193.3	0.92	0.79



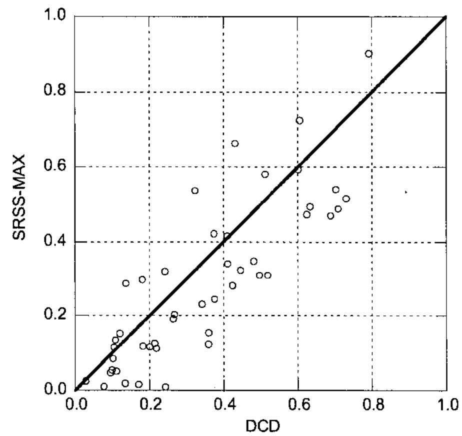
(a) Concrete



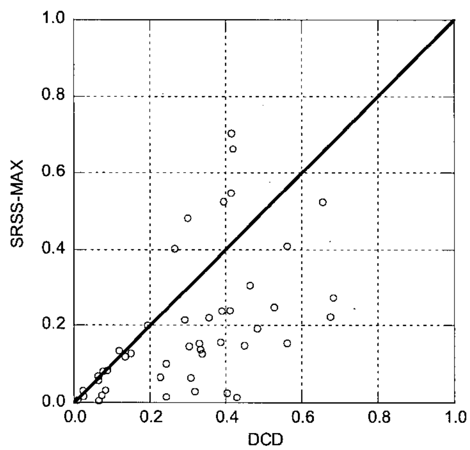
(b) Shear Tie



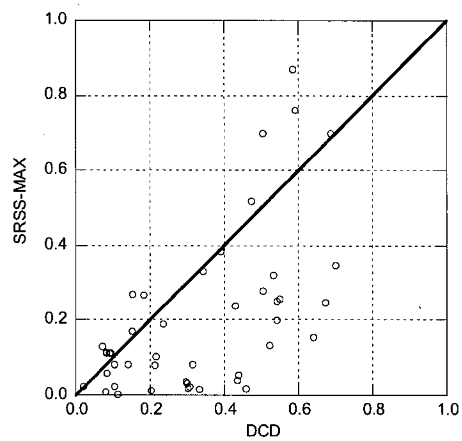
(c) Rebar 1



(d) Rebar 2

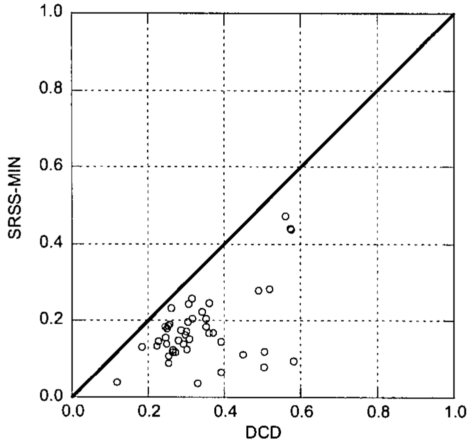


(e) Rebar 3

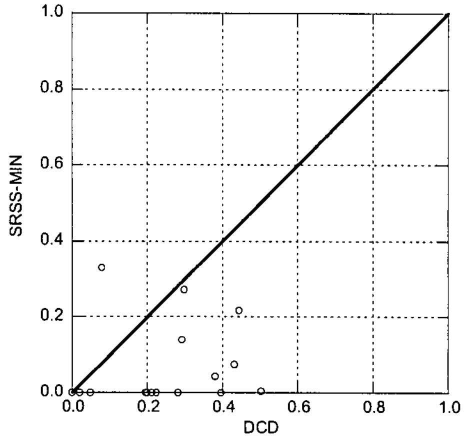


(f) Rebar 4

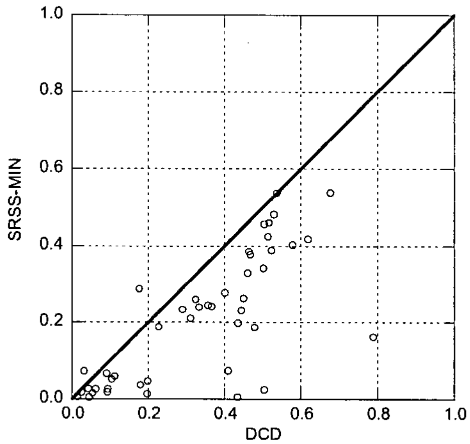
Figure 3.8-107(13) Comparison for SRSS Maximum Case (Load ID = 7441)



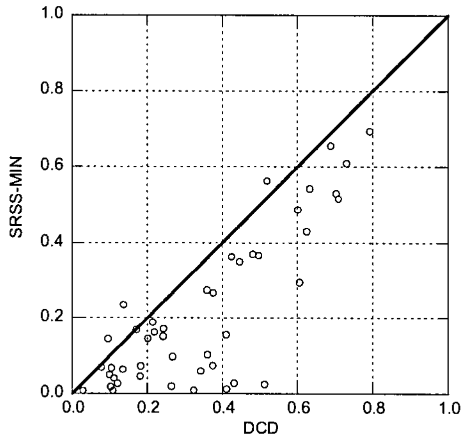
(a) Concrete



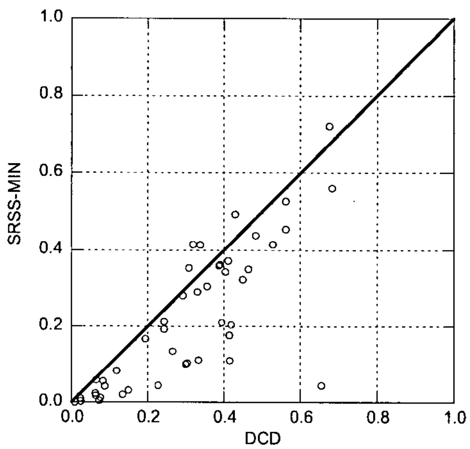
(b) Shear Tie



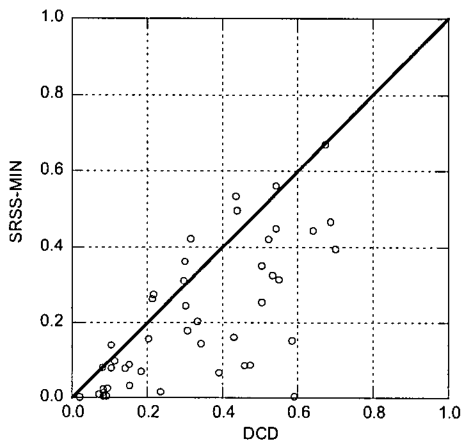
(c) Rebar 1



(d) Rebar 2

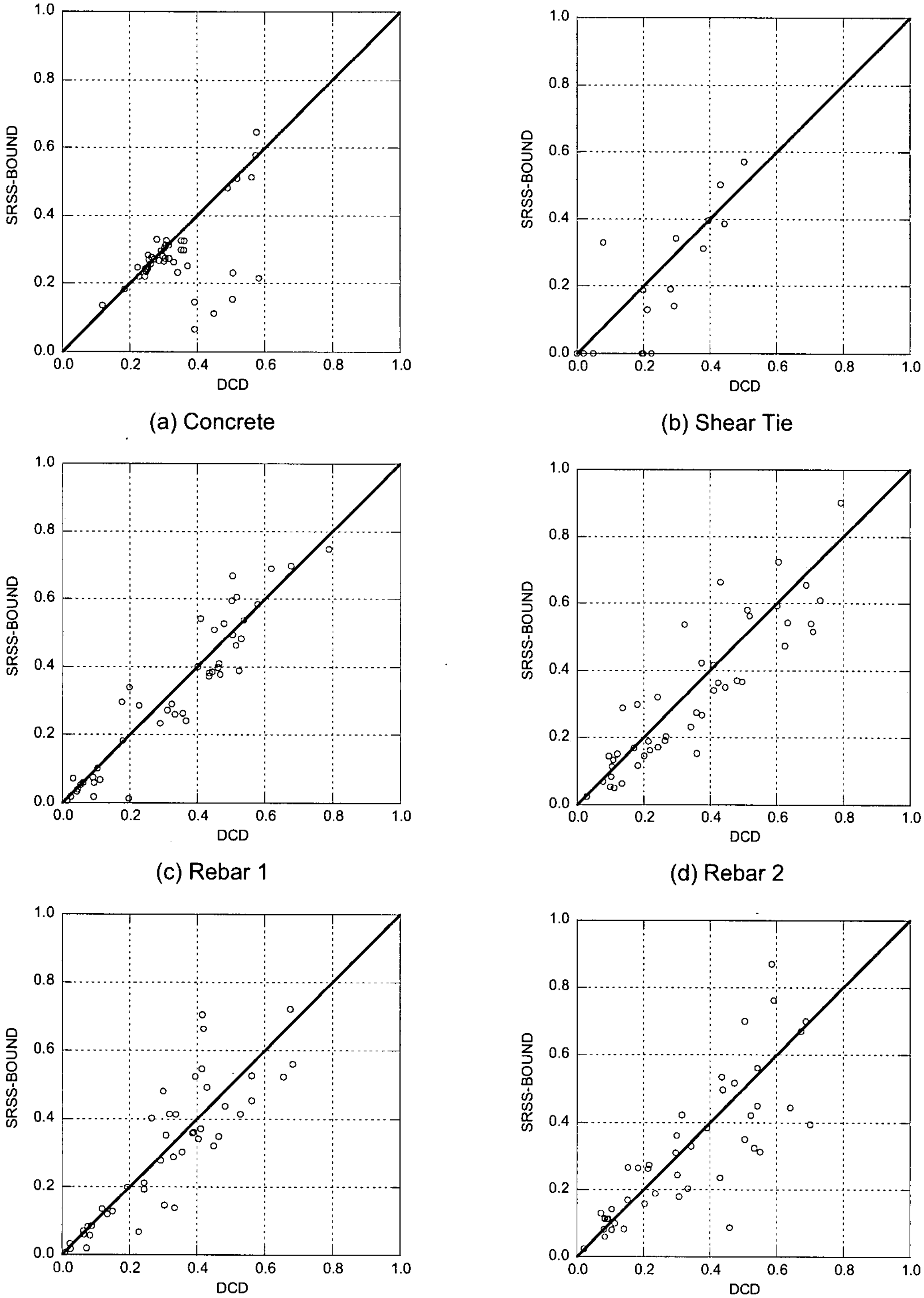


(e) Rebar 3



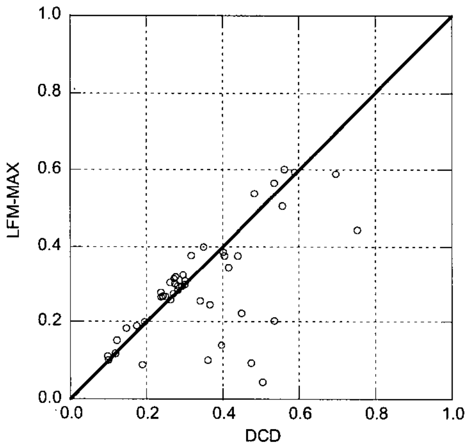
(f) Rebar 4

Figure 3.8-107(14) Comparison for SRSS Minimum Case (Load ID = 7441)

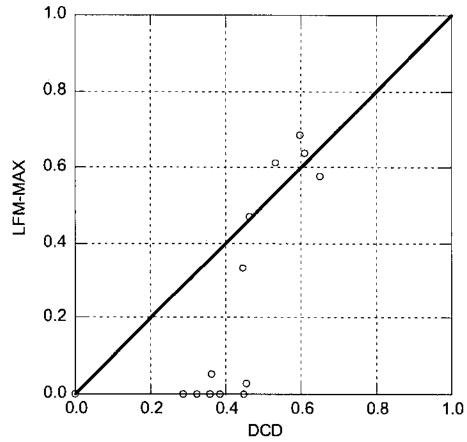


(a) Concrete (b) Shear Tie
(c) Rebar 1 (d) Rebar 2
(e) Rebar 3 (f) Rebar 4

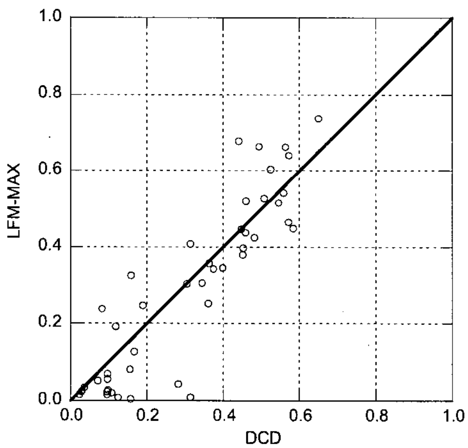
Figure 3.8-107(15) Comparison for SRSS Bound Case (Load ID = 7441)



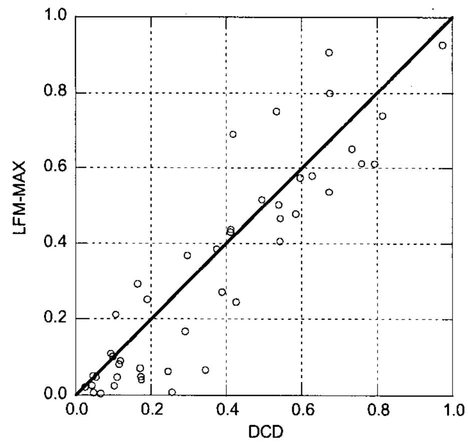
(a) Concrete



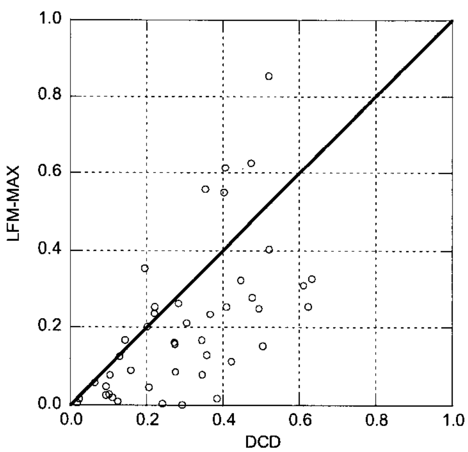
(b) Shear Tie



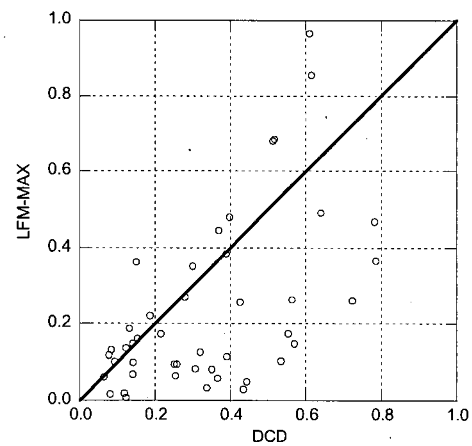
(c) Rebar 1



(d) Rebar 2

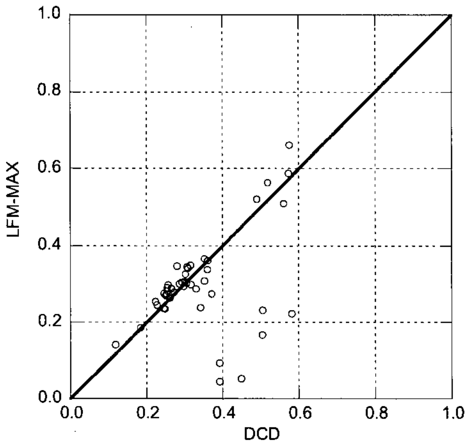


(e) Rebar 3

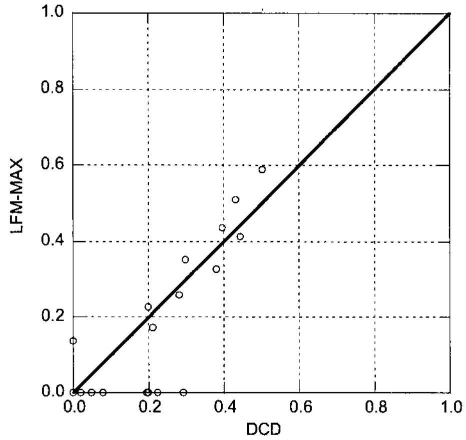


(f) Rebar 4

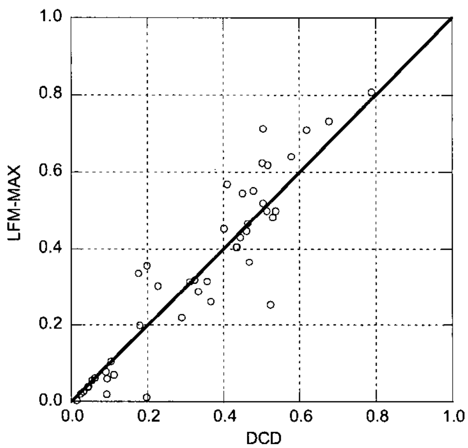
Figure 3.8-107(16) Comparison for Load Factored Method Maximum Case (Load ID = 7241)



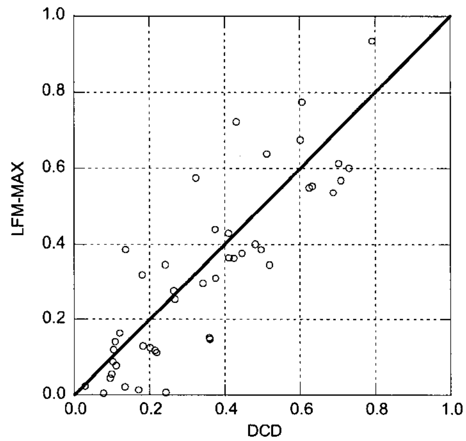
(a) Concrete



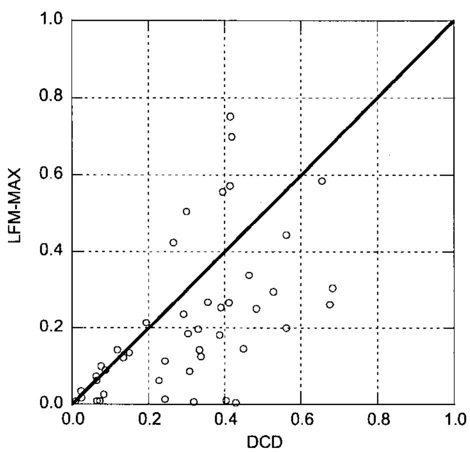
(b) Shear Tie



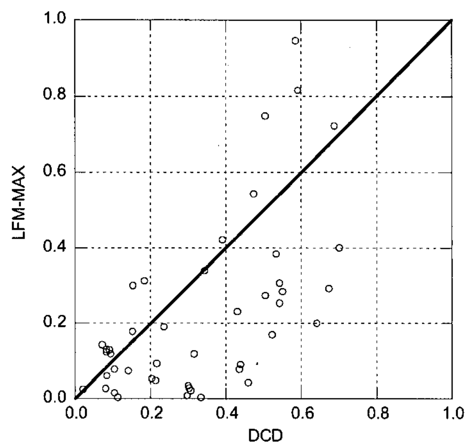
(c) Rebar 1



(d) Rebar 2

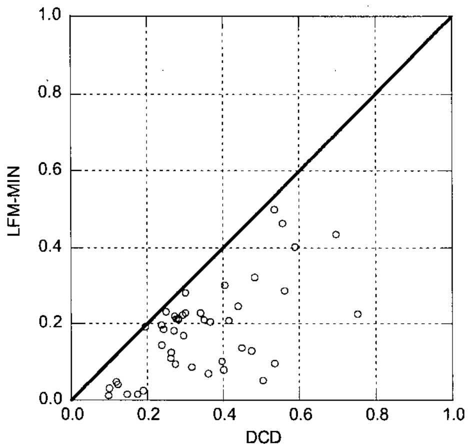


(e) Rebar 3

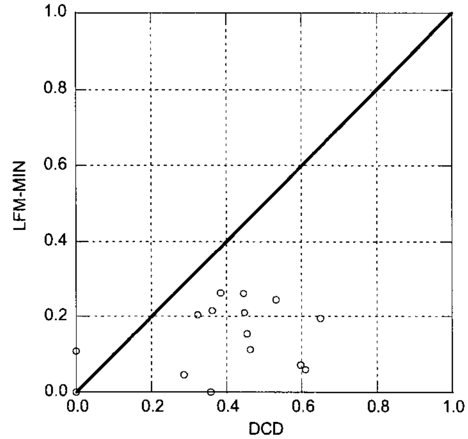


(f) Rebar 4

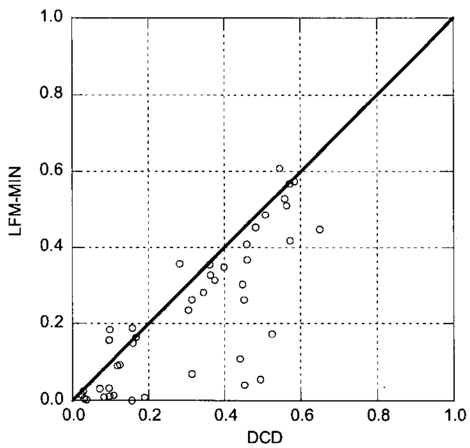
Figure 3.8-107(17) Comparison for Load Factored Method Maximum Case (Load ID = 7441)



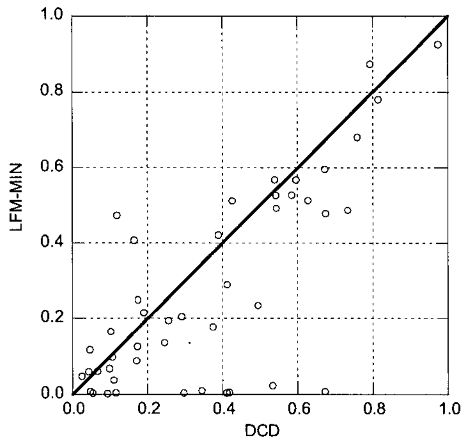
(a) Concrete



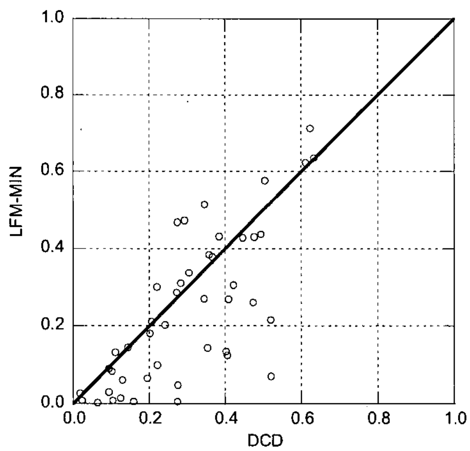
(b) Shear Tie



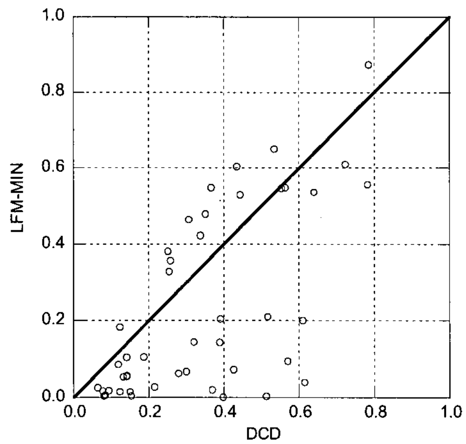
(c) Rebar 1



(d) Rebar 2



(e) Rebar 3



(f) Rebar 4

Figure 3.8-107(18) Comparison for Load Factored Method Minimum Case (Load ID = 7241)

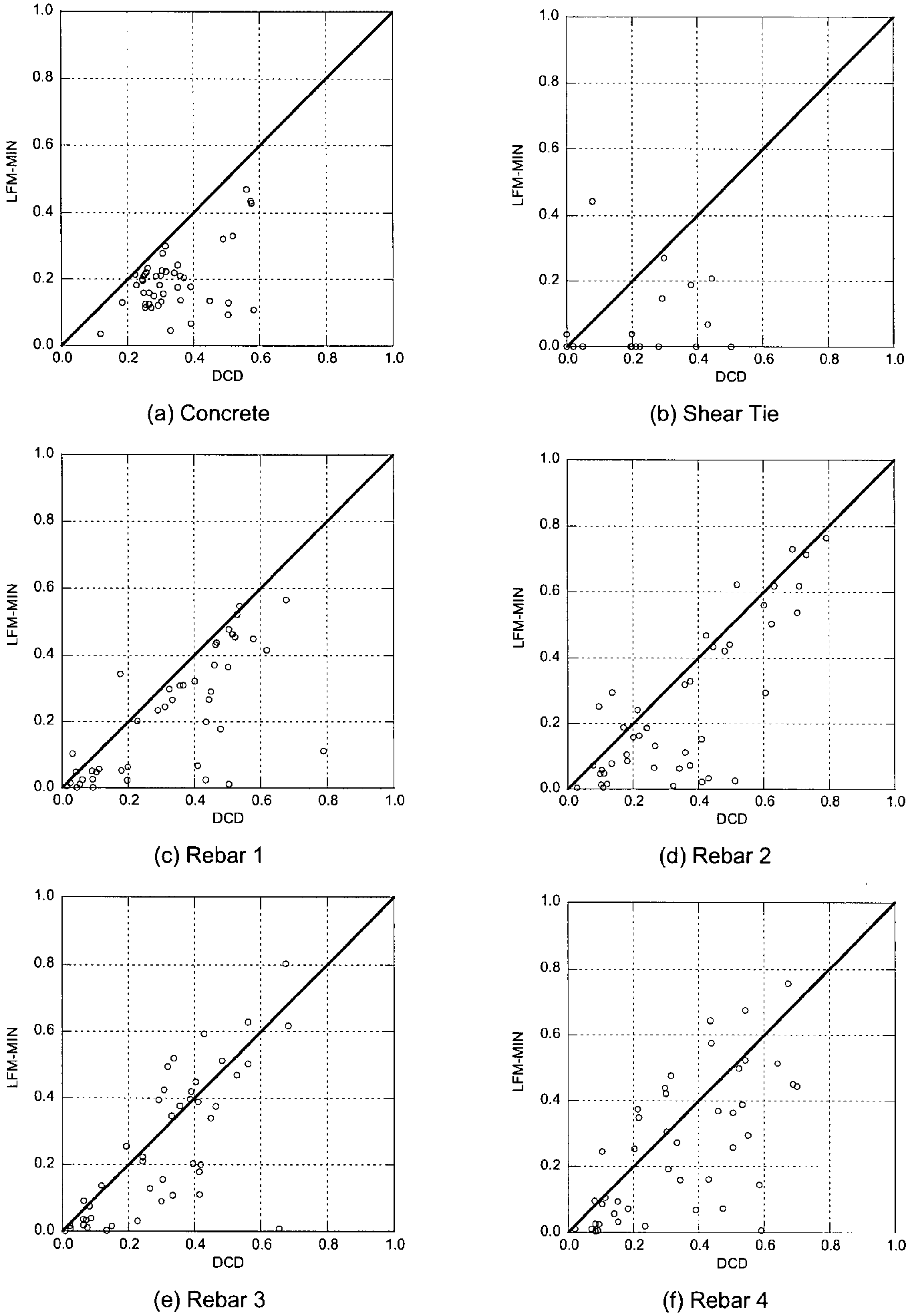
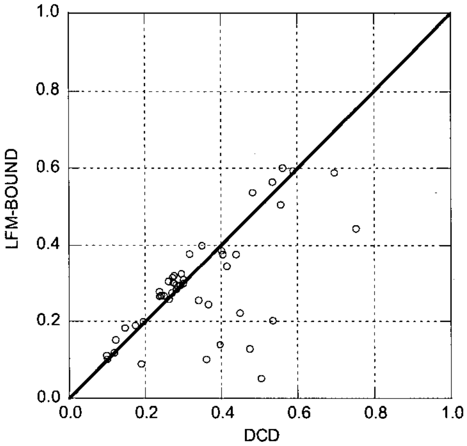
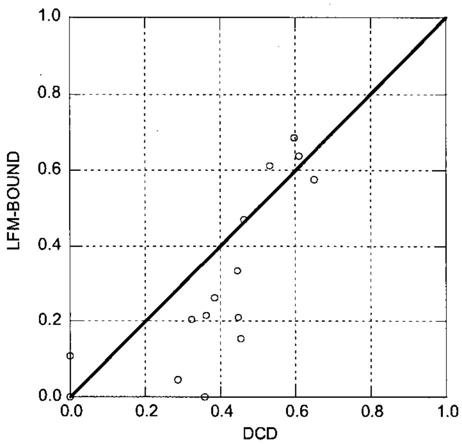


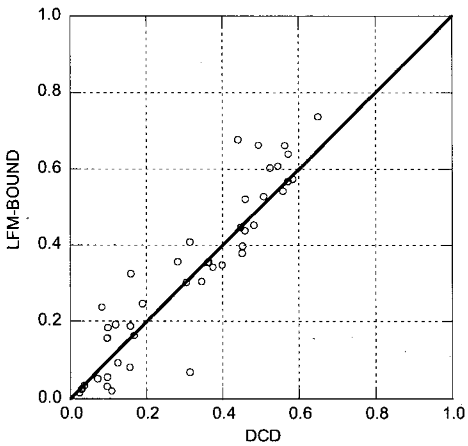
Figure 3.8-107(19) Comparison for Load Factored Method Minimum Case (Load ID = 7441)



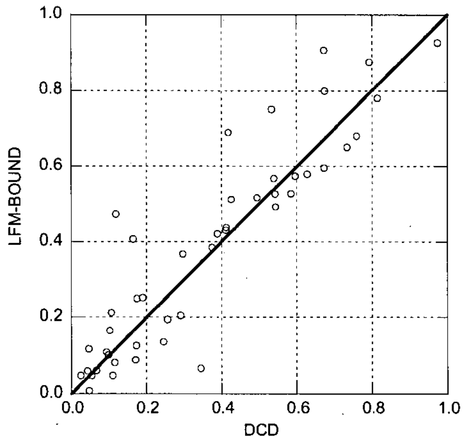
(a) Concrete



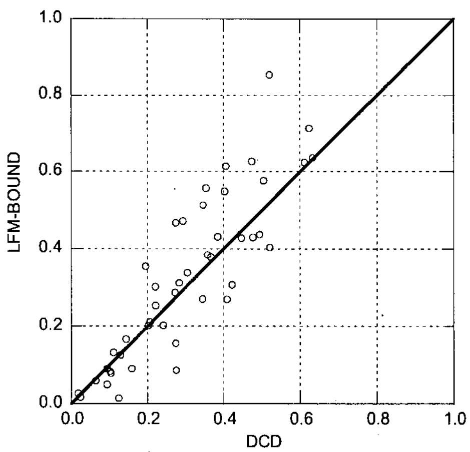
(b) Shear Tie



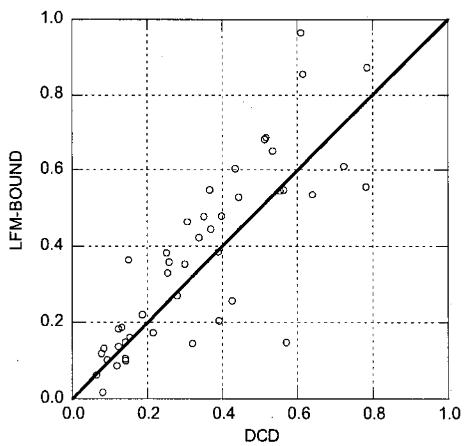
(c) Rebar 1



(d) Rebar 2

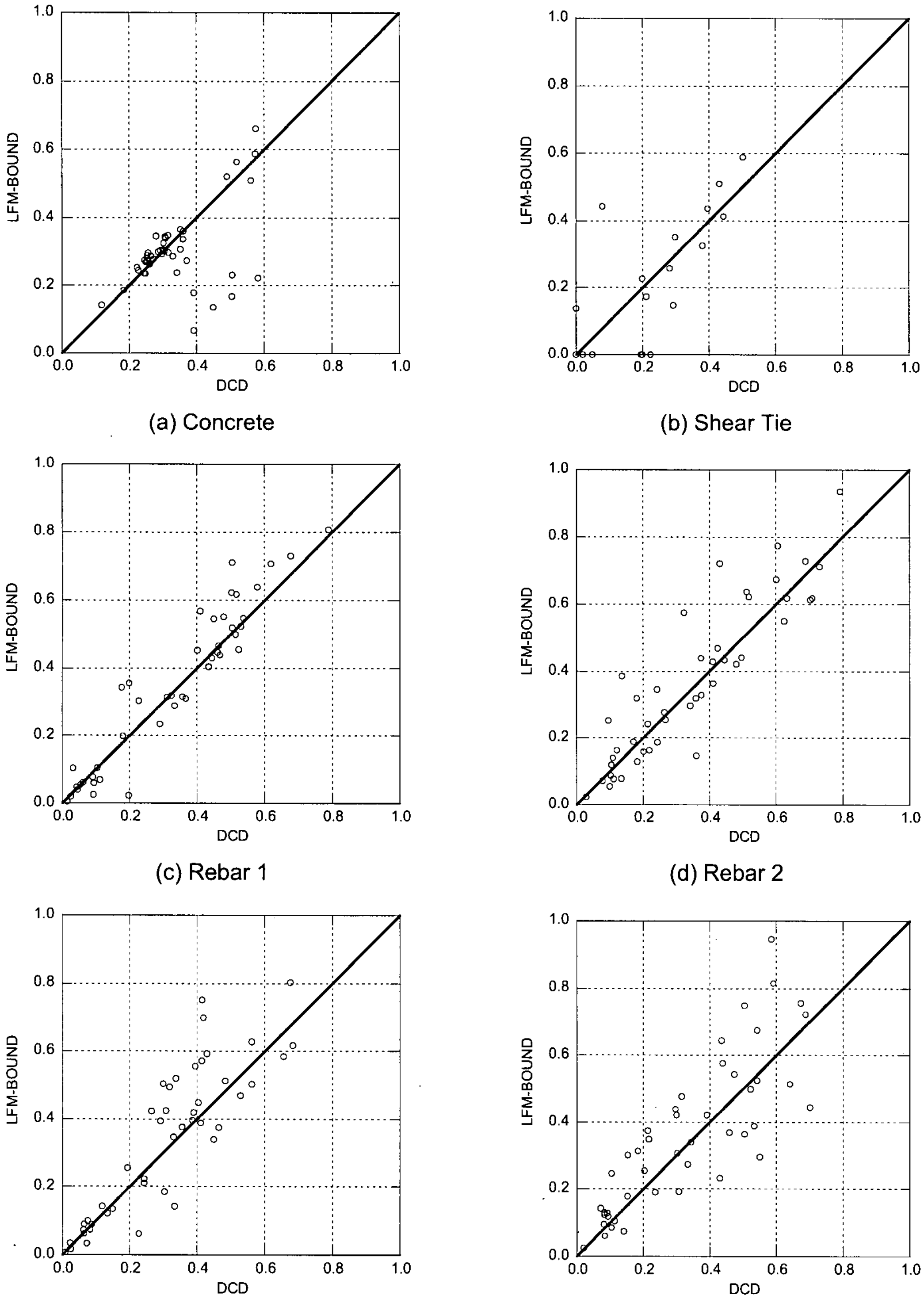


(e) Rebar 3



(f) Rebar 4

Figure 3.8-107(20) Comparison for Load Factored Method Bound Case (Load ID = 7241)



(a) Concrete (b) Shear Tie

(c) Rebar 1 (d) Rebar 2

(e) Rebar 3 (f) Rebar 4

Figure 3.8-107(21) Comparison for Load Factored Method Bound Case (Load ID = 7441)

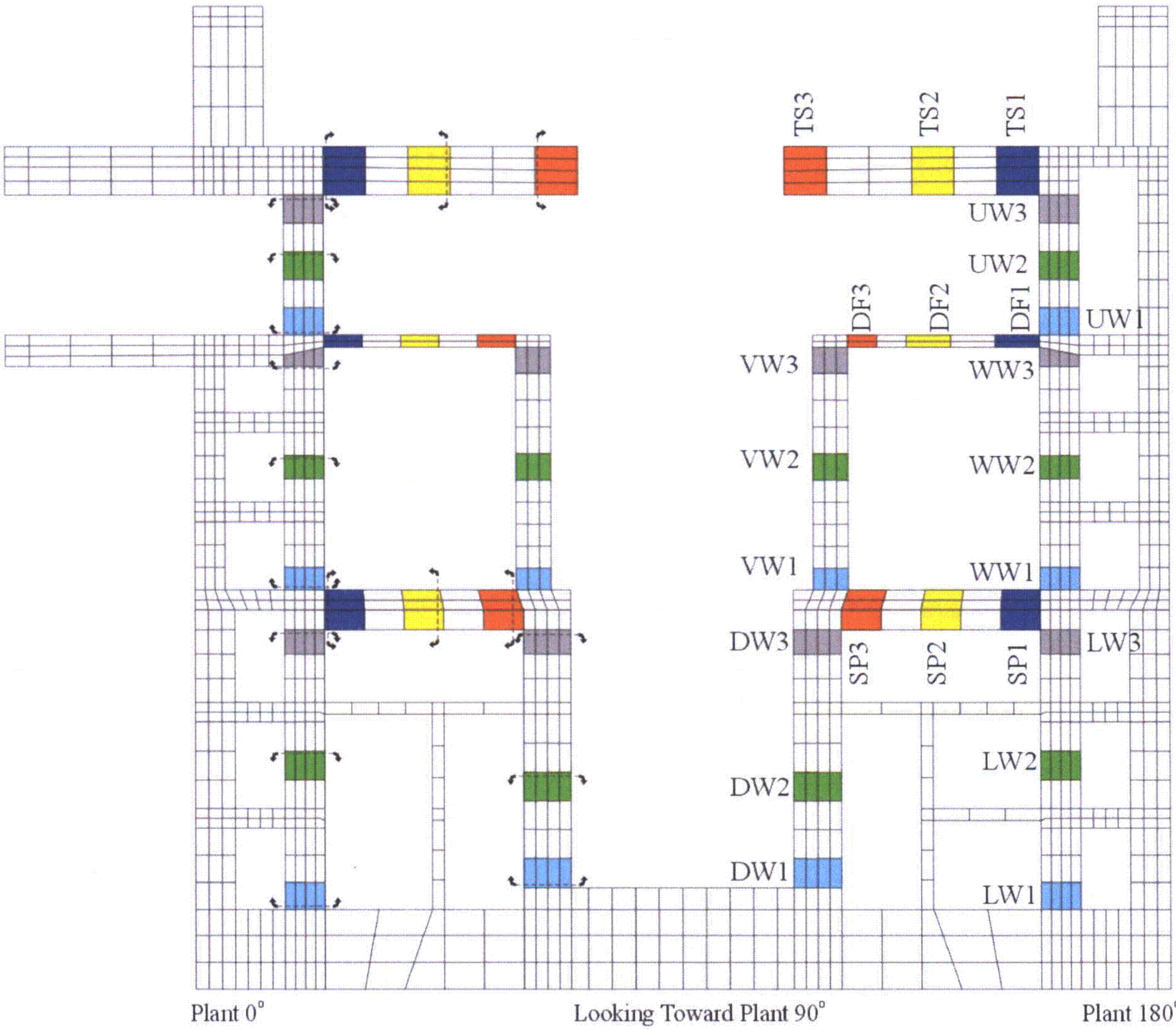


Figure 3.8-107(22) Schematic for Section Cuts, Elevation View

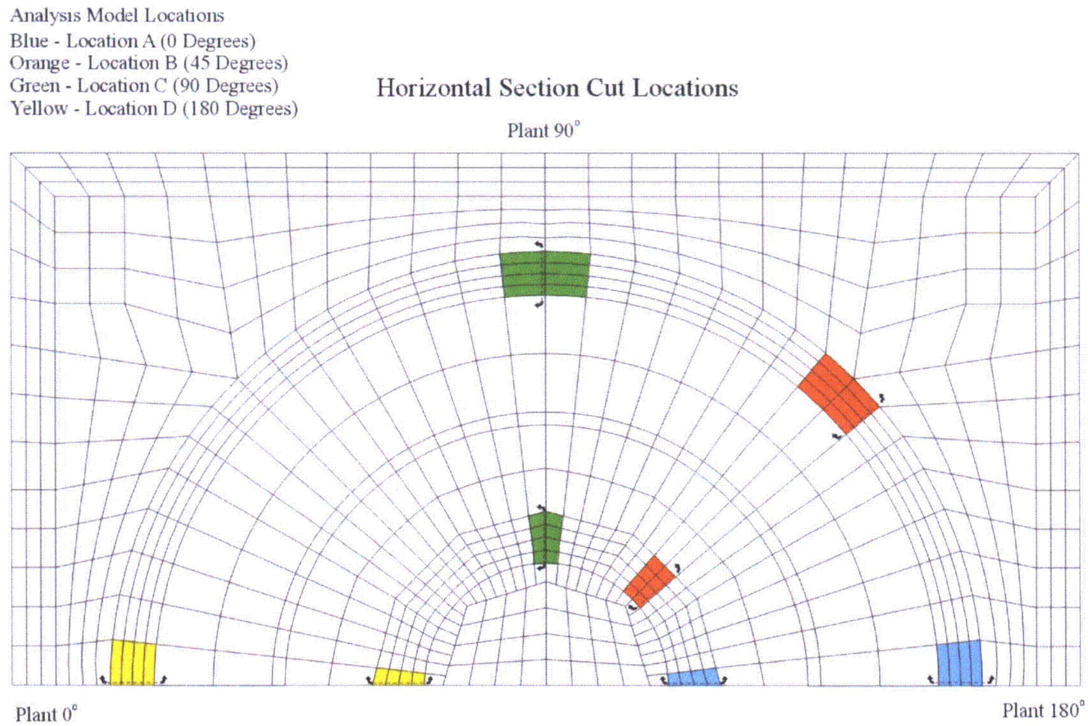


Figure 3.8-107(23) Schematic for Section Cuts, Plan View

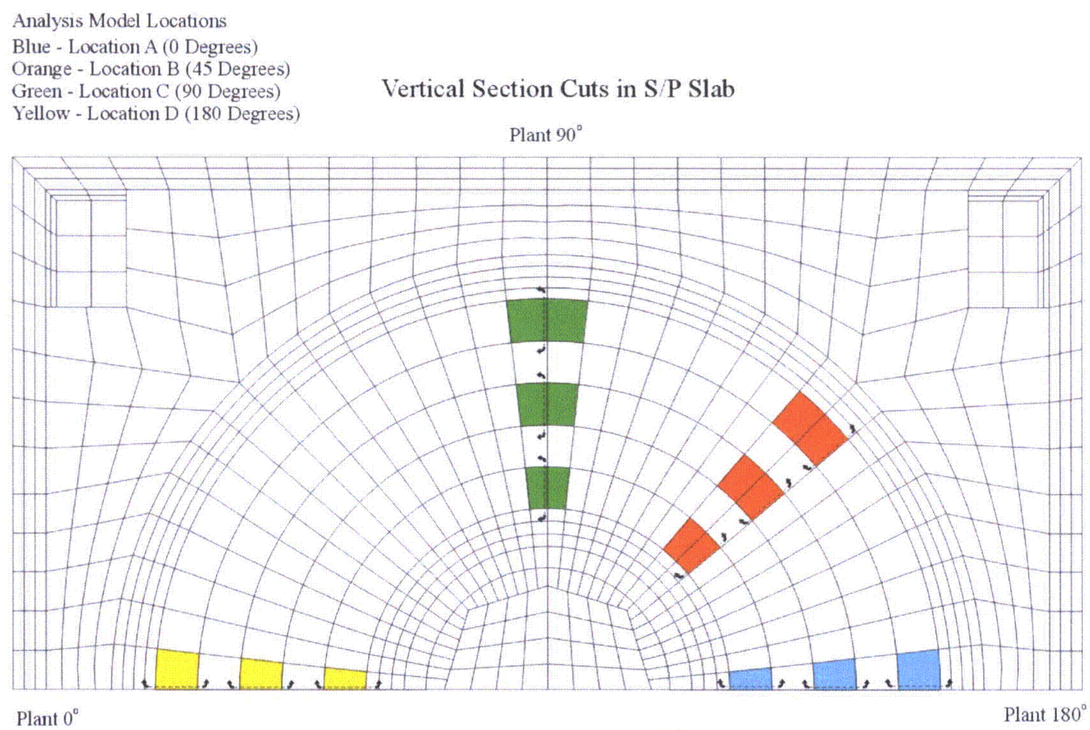


Figure 3.8-107(24) Schematic for Section Cuts in Top Slab, Plan View

DCD Impact

Markups of DCD Tier 2 Revision 5 were provided in MFN 08-432, which was transmitted to the NRC on May 1, 2008 and MFN 08-432, Supplement 1, which was transmitted to the NRC on September 11, 2008.

NRC RAI 3.8-107, Supplement 3

As a result of the staff's review of the GEH response transmitted in GEH letter MFN 08-432, Supplement 2, dated September 30, 2008, GEH is requested to address the following two remaining items:

Part (b)(3):

The information provided in the RAI response does not demonstrate that the approach in AIJ Article 15 (provided as Attachment 3.8-107(3) to the RAI response) is the same as the analytical approach in Section 4.2 of the Shimizu SSDP validation report (Enclosure 2 to GEH letter MFN 06-416 dated 11/6/06). While the equations for most of the concrete section properties (e.g., A_e, g, I_g) match, the equations for solving the compressive stress in the concrete, and rebar stresses in tension and compression could not be matched. Furthermore, the equations in the additional Reference 3 (Reinforced Concrete Analysis and Design textbook excerpt provided as Attachment 3.8-107(4)) also do not match the equations in the AIJ Article 15. Therefore, GEH is requested to verify the equations used in the SSDP computer code by comparing the quantitative results for the sample problems performed in Sections 4.2.1 through 4.2.3 of the validation report with the use of the equations presented in the Reference 2 concrete textbook or other conventional concrete textbook. This approach would validate the use of the SSDP computer code for design of reinforced concrete members for the ESBWR.

Part (c):

The study performed demonstrates that the use of uncracked properties for mechanical loads is acceptable for determining the concrete stresses; however, the approach did not adequately demonstrate the approach for stresses in the rebars. This was evident by the fact that so many rebar stress ratios for Case 1/Case 2, in RAI Table 3.8-107(18), were less than 1.0 and in some cases substantially less than 1.0. The RAI response indicates that these locations are "typically" at locations of "relatively" low stress that are "not controlling." This statement alone is not considered sufficient to address the numerous tabulated ratios less than 1.0. Therefore, unless the effects of concrete cracking is considered in the mechanical load analyses, GEH is requested to confirm that in the regions where the rebar stress ratios are less than 1.0, these rebar stresses indeed do not control the design. This could be achieved by confirming that at locations where the stress ratios are less than 1.0 one or more of the following occurs: (1) the section design at the location is based on other sections adjacent to or at a different azimuth where the ratios are equal to or greater than 1.0, (2) the rebar stresses are sufficiently small to compensate for the ratio being less than 1.0, and/or (3) there is sufficient margin between the rebar stress/section design and code limits to accommodate the lower stress ratios.

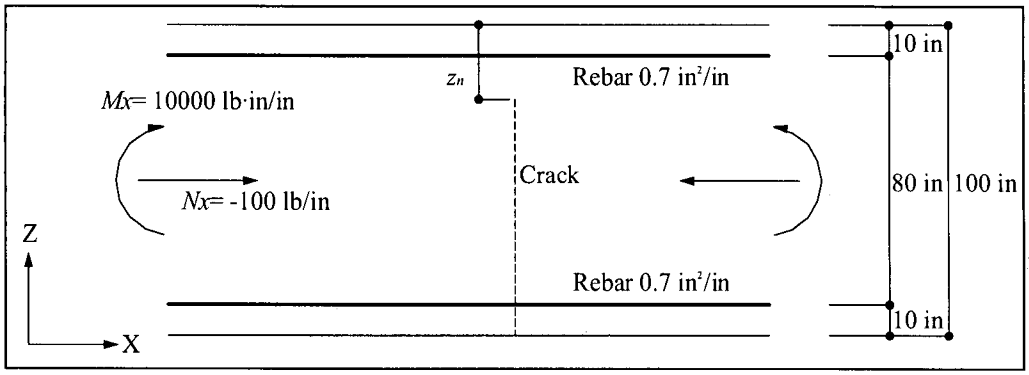
GEH Response

Part (b)(3)

The equations used in the SSDP-2D computer code are verified by comparing the quantitative results for the most representative sample problem for a partially cracked concrete section described in Section 4.2.3 of the SSDP-2D validation report (Enclosure 2 to GEH letter MFN 06-416 dated 11/7/06) with the results from equations presented in Section 1.13.2 of the text book by Mr. S.S. Ray (Attachment 3 to GEH letter MFN 08-432 S01 dated 9/11/08).

The hand calculation using the equations presented in Section 1.13.2 of the textbook by Mr. S.S. Ray is as follows:

1. Problem Descriptions



a. Material Properties

E_C: Young's modulus of concrete (3.61×10^6 psi)

E_S: Young's modulus of rebar (2.90×10^7 psi)

m: Young's modulus ratio

$$m = E_s / E_c$$
$$= 2.90\times10^7 / 3.61\times10^6$$
$$= 8.03$$

b. Sectional Dimensions

H: Thickness (100 in)

b: Width (1 in)

d: Depth of tensile rebar from compression face (90 in)

d': Depth of cover concrete at tension side (10 in)

c. Rebar Arrangement

A_s: Area of tension rebar (0.7 in^2/in)

A_s': Area of compression rebar (0.7 in^2/in)

d. Applied Forces

N_x: Compressive force (-100 lb/in)

M_x: Bending moment (10000 lb·in/in)

e: $= M_x / |N_x| = 10000 / |100| = 100$ (in)

g: Depth of central axis of bending moment from compressive face (in)

$$\begin{aligned} g &= H/2 \\ &= 100/2 \\ &= 50 \end{aligned}$$

2. Calculation Details

Find the neutral axis by iterations to satisfy the following equation for solution convergence:

$$x_1 - x_2 = 0.0$$

where, x_1: Initial assumed value

x_2: Depth of neutral axis from compressive face calculated as follows:

$$x_2 = \frac{d}{\left(1 + \frac{f_s}{mf_c}\right)}$$

f_c : Axial Stress of Concrete (psi)

$$f_c = \frac{k_1 N_x}{k_3\left(1 - \frac{d'}{d}\right)A_s' + k_2 bd}$$

f_s : Axial Stress of Tension Rebar (psi)

$$f_s = \frac{f_c(k_3 A_s' + 0.5bx_1) - N_x}{A_s}$$

$$k_1 = \left[\frac{(e-g)}{d} + 1\right]$$

$$k_2 = \left(\frac{x_1}{2d}\right)\left(1 - \frac{x_1}{3d}\right)$$

$$k_3 = m\left(1 - \frac{d'}{x_1}\right)$$

For $x_1 = 34.1580$ (in), equation for solution convergence is satisfied. Other variables are determined as follows:

$$k_1 = \left[\frac{(100-50)}{90} + 1\right]$$
$$= 1.5556$$

$$k_2 = \left(\frac{34.1580}{2\times 90}\right)\left(1 - \frac{34.1580}{3\times 90}\right)$$
$$= 0.1658$$

$$k_3 = 8.0332\times\left(1 - \frac{10}{34.1580}\right)$$
$$= 5.6814$$

$$f_c = \frac{1.5556\times 100}{5.6814\times\left(1-\frac{10}{90}\right)\times 0.7 + 0.1658\times 1.0\times 90}$$
$$= 8.4282$$

$$f_s = \frac{8.4282\times(5.6814\times 0.7 + 0.5\times 1.0\times 34.1580) - 100}{0.7}$$
$$= 110.6629$$

f_s' : Axial stress of compression rebar (psi)

$$f_s' = mf_c\frac{x_1 - d'}{x_1}$$
$$= 8.0332\times 8.4282\times\frac{34.1580-10}{34.1580}$$
$$= 47.8842$$

$$x_2 = \frac{90}{\left(1 + \frac{110.6629}{8.0332\times 8.4282}\right)}$$
$$= 34.1624$$
$$\approx x_1$$

3. Results

The hand calculation results are in good agreement with the SSDP-2D results as shown in Table 3.8-107(19).

Part (c)

To confirm section design adequacy in the regions where the rebar stress ratios are less than 1.0, the stress results of Case 2 (Thermal + Pressure nonlinear analysis) of the demonstration analysis are first converted to section forces and moments for all section cuts of the RCCV including the RPV Pedestal, Wetwell, Drywell, Suppression Pool (S/P) Slab and Top Slab.

These Thermal + Pressure section forces and moments are then combined with the section forces and moments of other loads calculated by NASTRAN linear elastic analyses for LOCA + SSE load combination (designated as CV-11b in DCD Tier 2 Table 3G.1-10) for stress calculations using SSDP-2D. The resulting stresses are summarized in Table 3.8-107(20).

The rebar stresses at all sections are within the code allowable. The highest ratio of calculated rebar stress to code allowable is 0.84 at element 98104 of the Top Slab. The concrete compressive stresses are also within the code allowable except at one element in the RPV Pedestal (element 5013 at the bottom). The concrete stress at this element is slightly higher (less than 10%) than the code allowable but it is very localized and the whole section is still below general yielding in view of large margins in the rebar stress; the highest rebar stress at this section is only 57% of the code allowable.

Furthermore, ignoring the concrete tensile stress in the design approach tends to result in overestimation of the concrete compressive stress as explained in GEH's response to NRC RAI 3.8-107 S02 (MFNs 08-432, dated 5/1/08 and 08-432 S01, dated 9/11/08) for the demonstration analysis. Therefore, it can be concluded that section design based nonlinear cracked analysis results for thermal loads and linear uncracked analysis results for other loads is an adequate design approach.

Table 3.8-107(19) Hand Calculation and SSDP-2D Results

Stresses	Hand Calculation	SSDP-2D
Concrete (psi)	-8.43	-8.50
Tension Rebar (psi)	110.7	110.6
Compression Rebar (psi)	-47.9	-47.7

Table 3.8-107(20) Rebar and Concrete Stresses of RCCV Selected Load Combination CV-11b

Location	Element ID	Concrete Stress (Mpa)		Primary Reinforcement Stress (MPa)				
		Calculated	Allowable	Calculated				Allowable
				Direction 1*		Direction 2*		
				In/Top	Out/Bottom	In/Top	Out/Bottom	
1 RPV	5006	-25.6	-27.9	-54.1	201.0	-126.7	32.5	361.6
Pedestal	5013	-30.3	-27.9	-54.5	204.9	-150.9	87.0	361.6
Bottom	5024	-25.1	-27.9	-43.0	201.1	-121.7	107.7	361.6
2 RPV	6006	-19.5	-27.9	-14.3	174.9	-94.4	113.0	361.6
Pedestal	6013	-26.1	-27.9	-22.7	132.9	-115.2	202.3	361.6
Mid-Height	6024	-27.7	-27.9	27.7	221.5	-104.4	237.1	361.6
3 RPV	6606	-11.3	-27.9	-48.7	105.6	-12.0	72.0	361.6
Pedestal	6613	-17.3	-27.9	-83.0	108.7	82.2	-48.8	361.6
Top	6624	-11.6	-27.9	-54.5	120.6	95.4	11.7	361.6
4 RCCV	1806	-25.0	-28.3	41.4	230.6	-88.1	222.7	364.4
Wetwell	1813	-20.1	-28.3	-21.6	166.6	-85.5	159.9	364.4
Bottom	1824	-22.8	-28.3	25.9	232.3	-86.4	190.9	364.4
5 RCCV	2606	-16.2	-28.2	21.8	216.5	-68.6	161.0	363.8
Wetwell	2613	-17.8	-28.2	18.2	209.4	-81.8	203.3	363.8
Mid-Height	2624	-20.7	-28.2	18.6	204.4	-92.8	207.6	363.8
6 RCCV	3406	-12.5	-28.2	112.3	263.3	89.2	182.6	363.8
Wetwell	3413	-10.3	-28.2	29.8	212.7	81.5	185.6	363.8
Top	3424	-11.9	-28.2	76.3	259.1	-47.0	188.0	363.8
7 RCCV	3606	-18.6	-27.7	55.6	227.2	-58.9	239.7	360.2
Drywell	3613	-13.7	-27.7	24.7	206.1	-47.8	229.3	360.2
Bottom	3624	-19.1	-26.7	33.8	167.1	-76.5	287.8	352.9
8 RCCV	4006	-15.3	-27.7	40.4	289.8	-50.5	177.6	360.2
Drywell	4013	-17.2	-27.7	29.9	260.9	-72.6	193.1	360.2
Mid-Height	4976	-17.9	-26.7	14.6	172.4	-76.7	154.7	352.9
9 RCCV	4406	-13.5	-27.7	33.7	269.3	-38.3	133.5	360.2
Drywell	4413	-13.3	-27.7	-13.1	220.0	-55.5	88.5	360.2
Top	4424	-12.4	-26.7	-25.6	199.6	94.2	48.7	352.9
12 S/P Slab	80003	-14.9	-28.3	141.1	214.5	-57.2	38.6	364.4
@ RPV	80007	-12.5	-28.3	90.6	173.7	-53.6	-15.5	364.4
	80012	-10.9	-28.3	57.8	162.4	-41.8	28.5	364.4
13 S/P Slab	80206	-24.5	-28.3	-15.4	139.8	-73.8	175.2	364.4
@ Center	80213	-24.6	-28.3	-18.0	169.3	-57.7	168.2	364.4
	80224	-23.5	-28.3	16.0	159.6	-65.1	192.1	364.4
14 S/P Slab	83306	-20.3	-28.3	-17.9	259.1	-41.7	99.1	364.4
@ RCCV	83313	-18.8	-28.3	-25.9	214.7	-25.6	49.7	364.4
	83324	-15.9	-28.3	-22.8	166.1	-39.6	67.2	364.4
15 Topslab	83406	-16.5	-26.2	139.7	-24.5	64.5	-30.2	349.2
@ Drywell Head	83413	-17.0	-26.2	249.1	110.0	131.0	-54.1	349.2
Opening	83424	-22.9	-26.2	250.1	-38.0	114.6	-23.3	349.2
16 Topslab	83506	-8.8	-26.6	155.0	17.2	9.3	-31.4	352.0
@ Center	83513	-9.6	-26.6	210.7	34.1	48.6	-36.1	352.0
	83524	-16.9	-27.2	204.2	-16.5	107.5	-26.6	356.6
17 Topslab	98120	-10.1	-26.6	58.5	47.2	44.8	25.5	352.0
@ RCCV	98135	-12.1	-26.6	125.7	32.9	132.2	-40.5	352.0
	98104	-22.2	-27.2	297.8	-24.3	134.4	-17.7	356.6

Note: Negative value means compression.
Note *: RCCV, Pedestal Direction1: Hoop Direction2: Vertical S/P Slab Direction1: Radial Direction2: Circumferential
Top slab Direction1: N-S Direction2 : E-W

DCD Impact

No DCD change is required in response to this RAI Supplement.