Lateral Impacts to PC Girders in Bridges with Intermediate Diaphragms

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Sponsored by Iowa Highway Research Board

Background

- Over-height vehicle impact frequency
- Intermediate diaphragm policies
- Bridge contractor preferences
- Previous research efforts

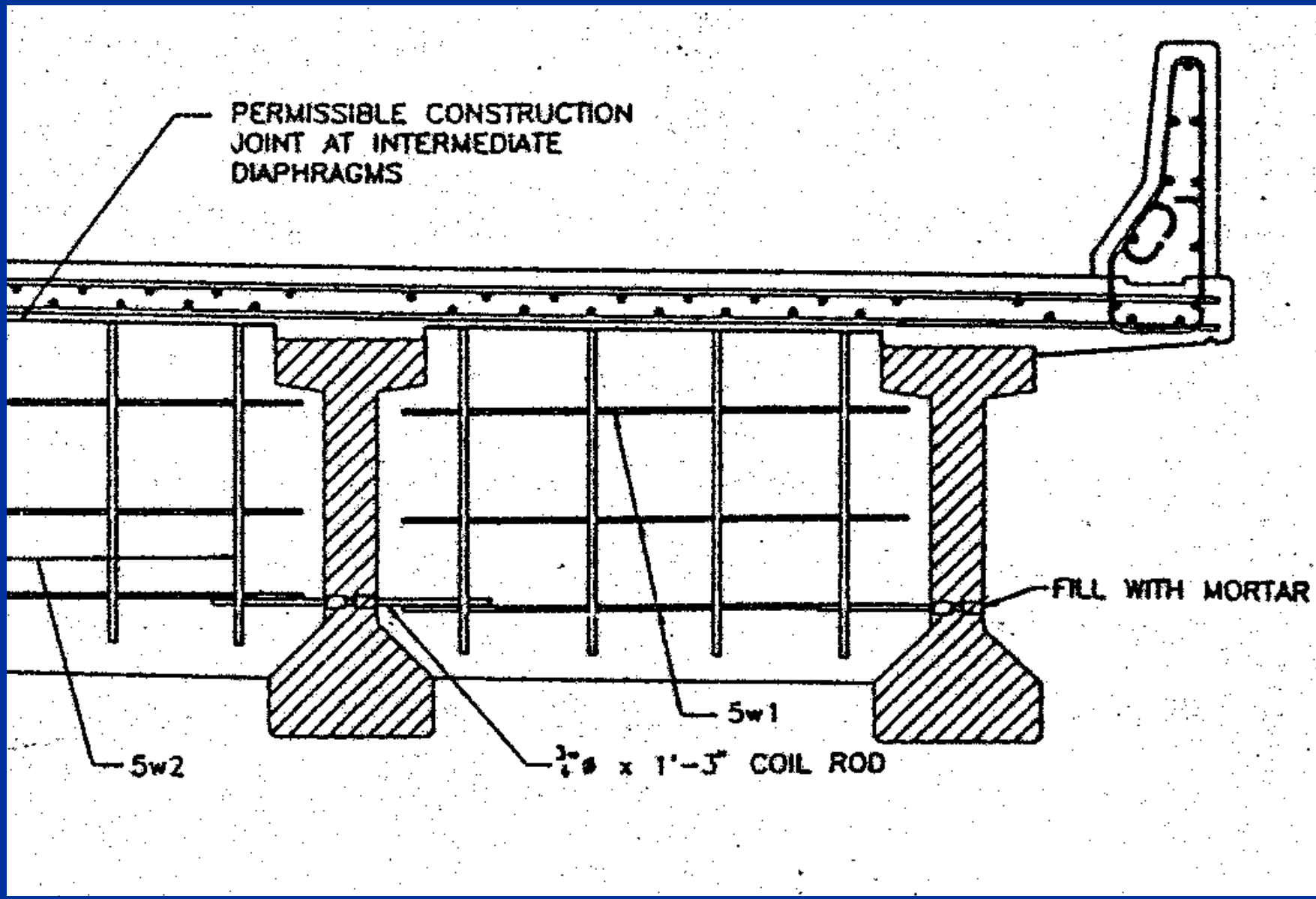
Objectives

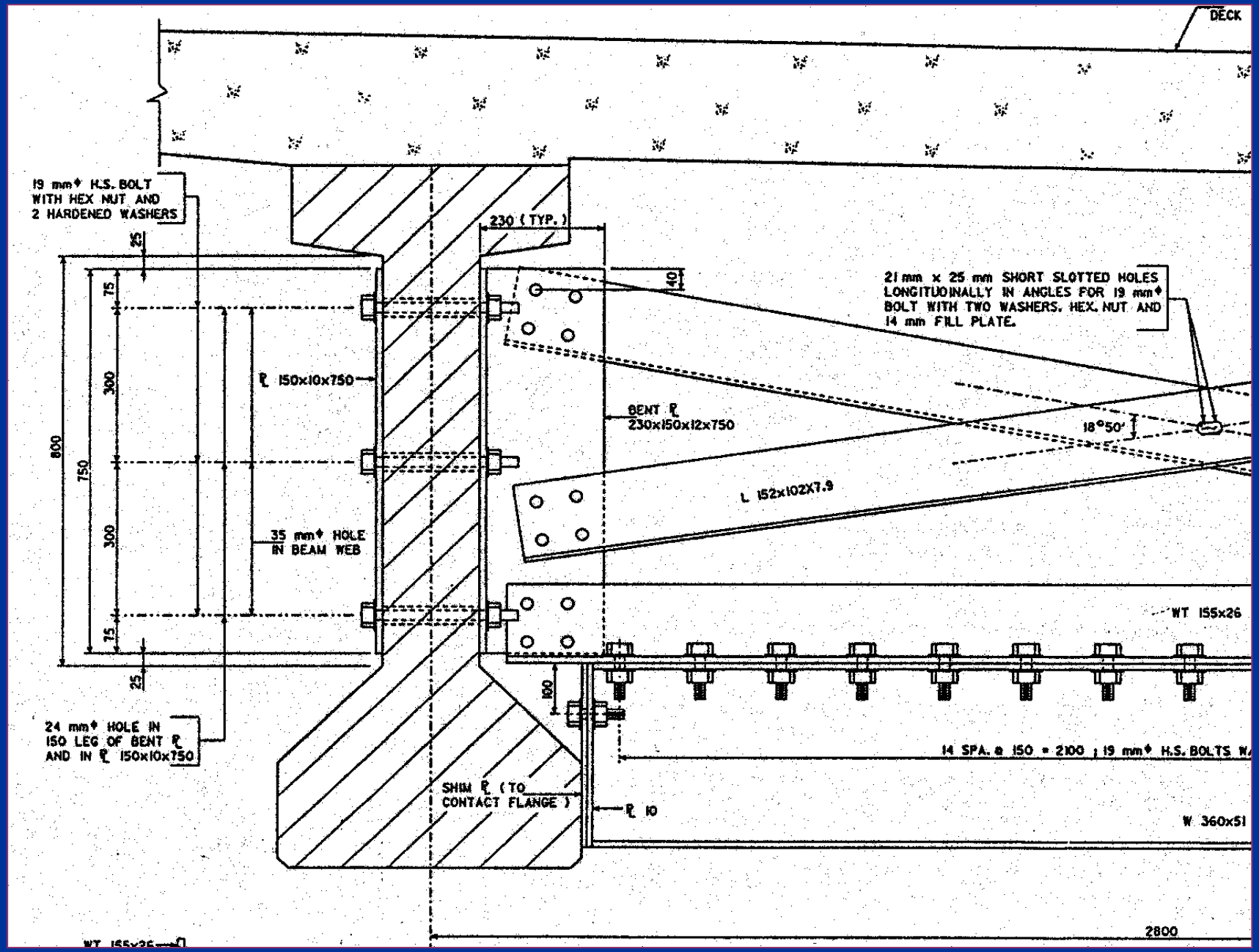
To evaluate the effectiveness of intermediate diaphragms for prestressed concrete (PC) girder bridges in distributing lateral loads that assimilate the effects of an over-height-vehicle load striking the bottom flange of an exterior girder.

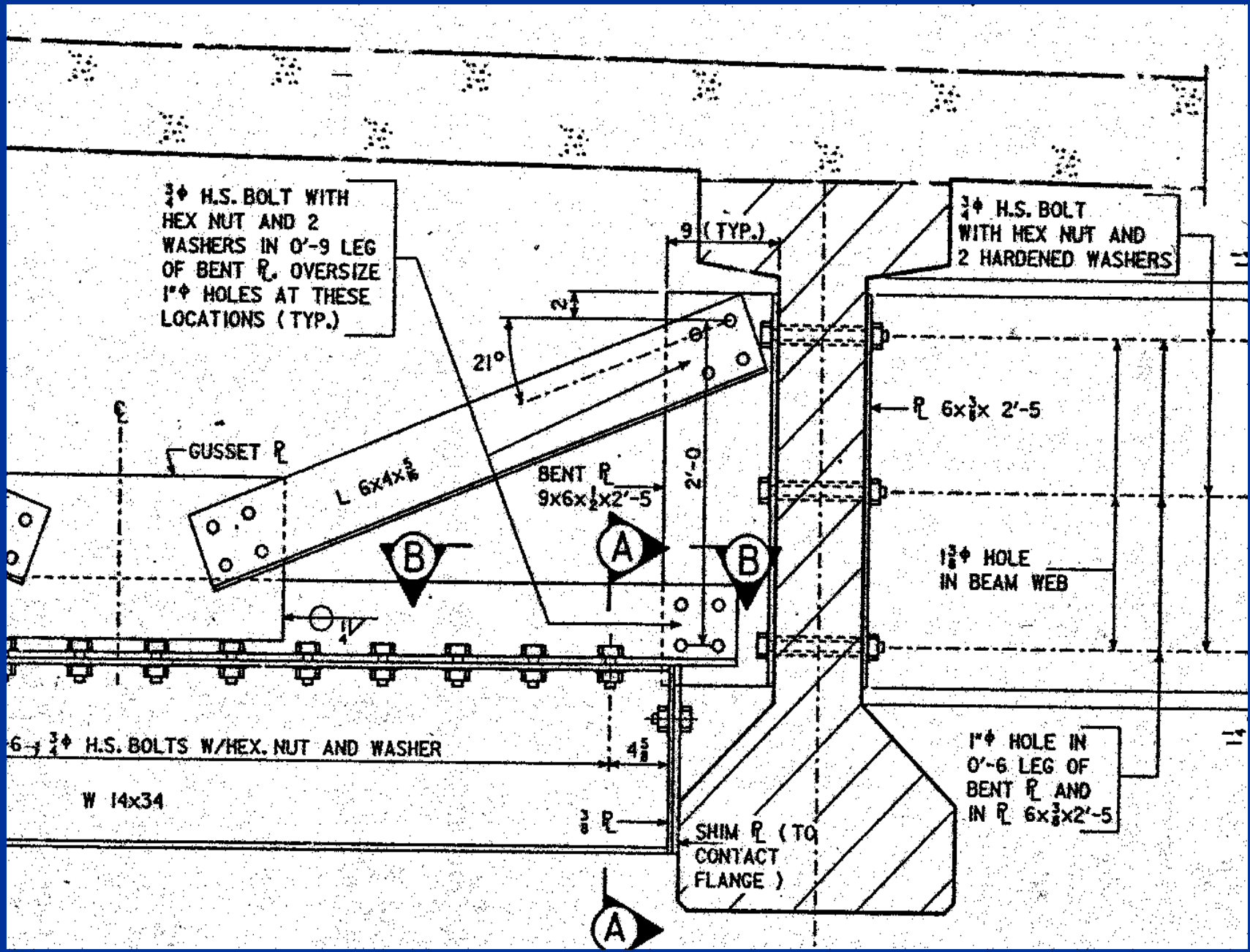
Bridge Geometrical Characteristics

- Prototype Bridges
- Spans
- Girders
- Horizontal Alignment

Intermediate Diaphragm Types


PERMISSIBLE CONSTRUCTION JOINT AT INTERMEDIATE DIAPHRAGMS
FILL WITH MORTAR
5w1
5w2
3/4" ø x 1'-3" COIL ROD


DECK
19 mm♦ H.S. BOLT WITH HEX NUT AND 2 HARDENED WASHERS
230 (TYP.)
40
21 mm x 25 mm SHORT SLOTTED HOLES LONGITUDINALLY IN ANGLES FOR 19 mm♦ BOLT WITH TWO WASHERS, HEX. NUT AND 14 mm FILL PLATE.
℄ 150x10x750
BENT ℄ 230x150x12x750
18°50'
L 152x102X7.9
35 mm♦ HOLE IN BEAM WEB
WT 155x26
800
750
300
300
75
75
25
24 mm♦ HOLE IN 150 LEG OF BENT ℄ AND IN ℄ 150x10x750
100
14 SPA. @ 150 = 2100 ; 19 mm♦ H.S. BOLTS W
SHIM ℄ (TO CONTACT FLANGE)
℄ 10
W 360x51
2800
WT 155x26


¾ϕ H.S. BOLT WITH HEX NUT AND 2 WASHERS IN 0'-9 LEG OF BENT ℄. OVERSIZE 1"ϕ HOLES AT THESE LOCATIONS (TYP.)
9 (TYP.)
¾ϕ H.S. BOLT WITH HEX NUT AND 2 HARDENED WASHERS
21°
℄ 6x⅜x 2'-5
GUSSET ℄
L 6x4x⅝
BENT ℄ 9x6x½x2'-5
2'-0
B
A
B
1⅛ϕ HOLE IN BEAM WEB
1¼
6-¾ϕ H.S. BOLTS W/HEX. NUT AND WASHER
4⅝
W 14x34
⅜ ℄
SHIM ℄ (TO CONTACT FLANGE)
1"ϕ HOLE IN 0'-6 LEG OF BENT ℄ AND IN ℄ 6x⅜x2'-5
A

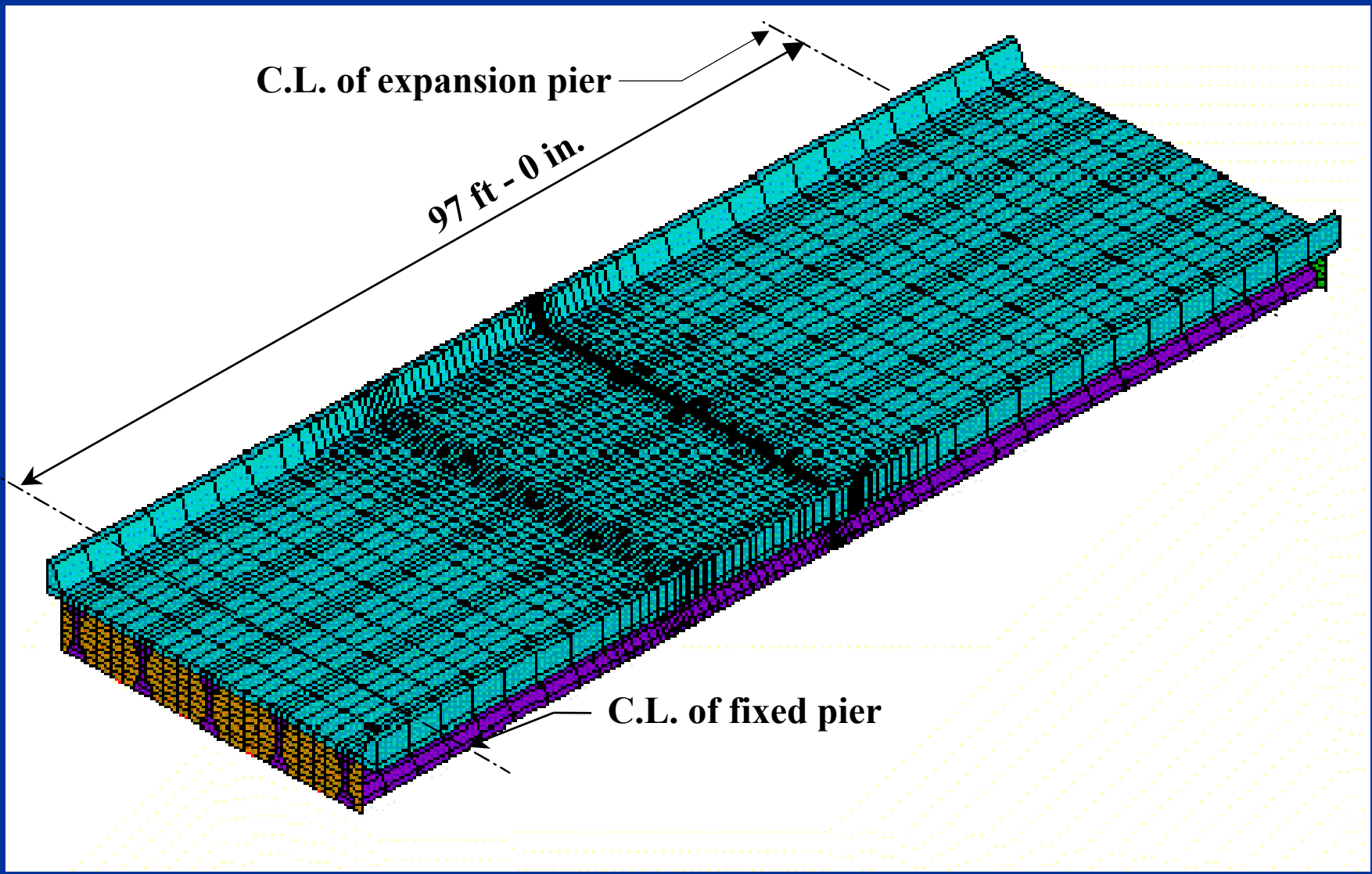
Analytical Approach

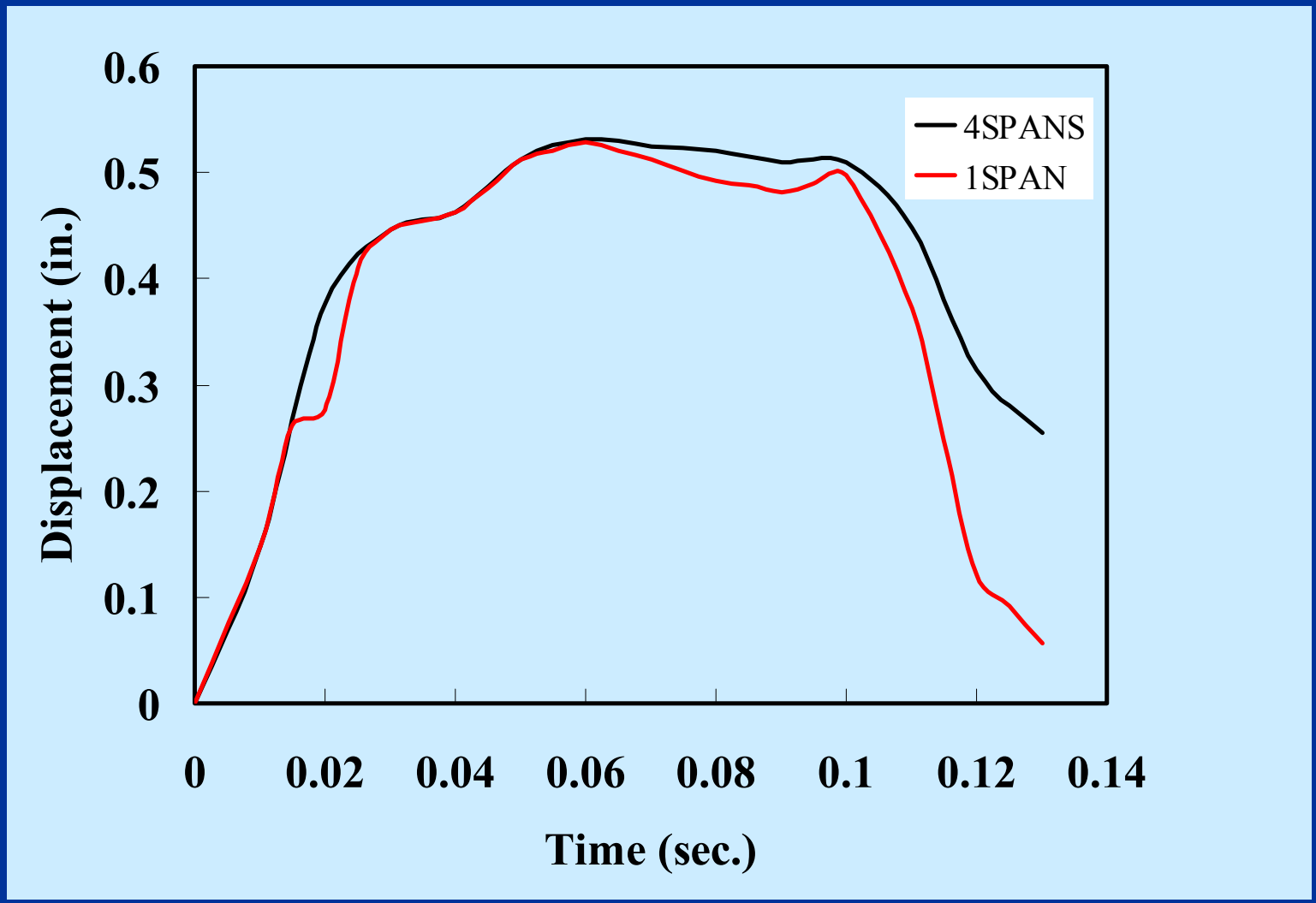
- Finite-element analysis
- Calibration
  - Experimental bridge
  - FE analysis
  - Comparison of results

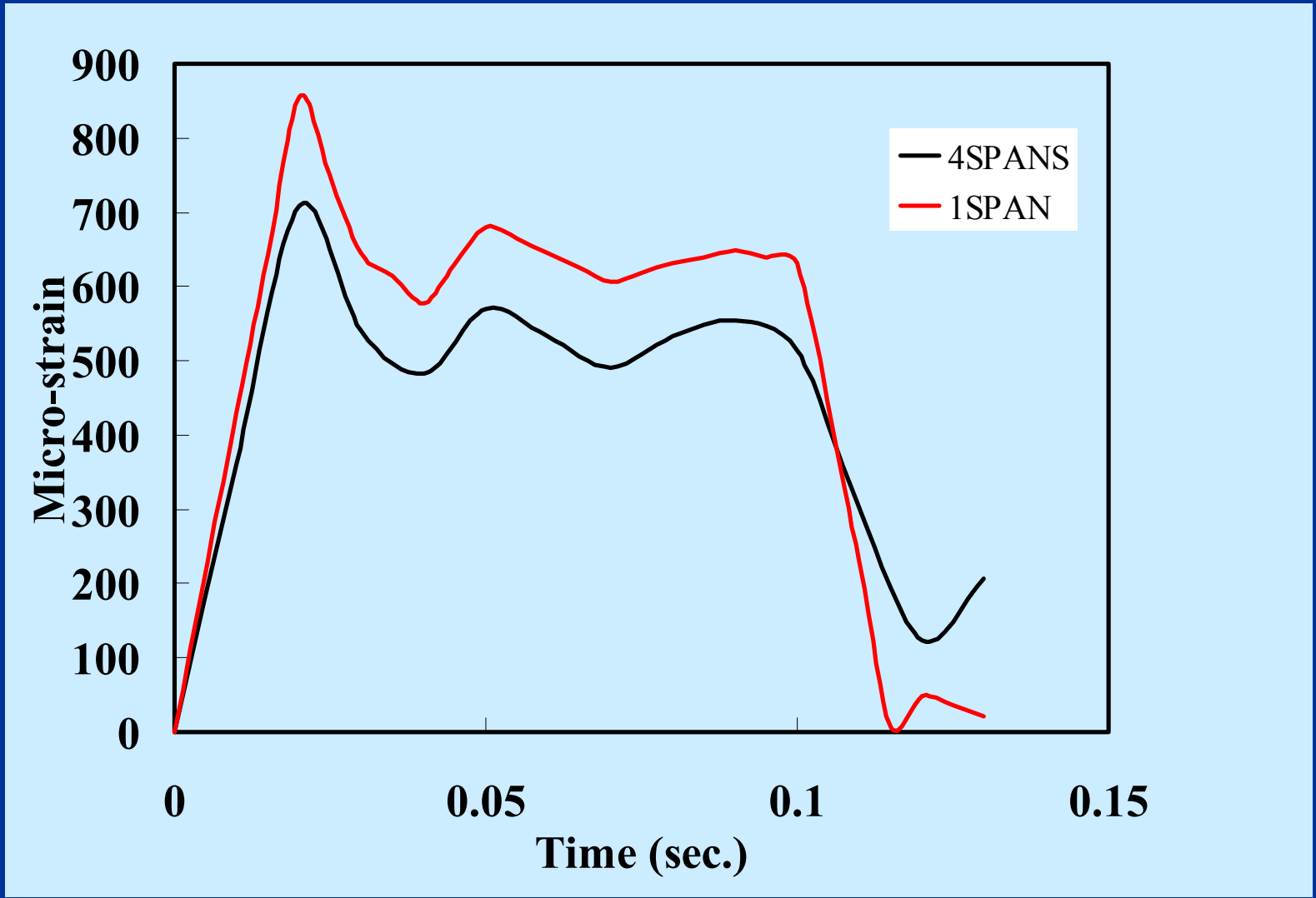
Analysis of Prototype Bridges

Four-span bridge model

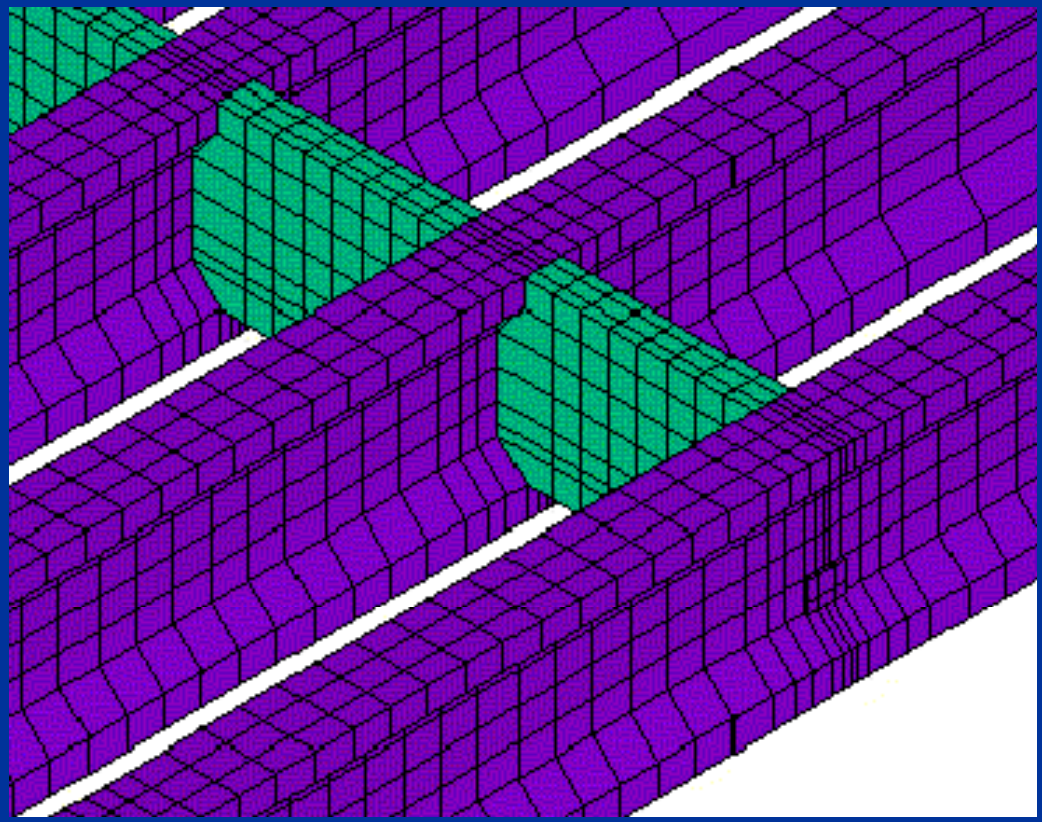
One-span bridge model

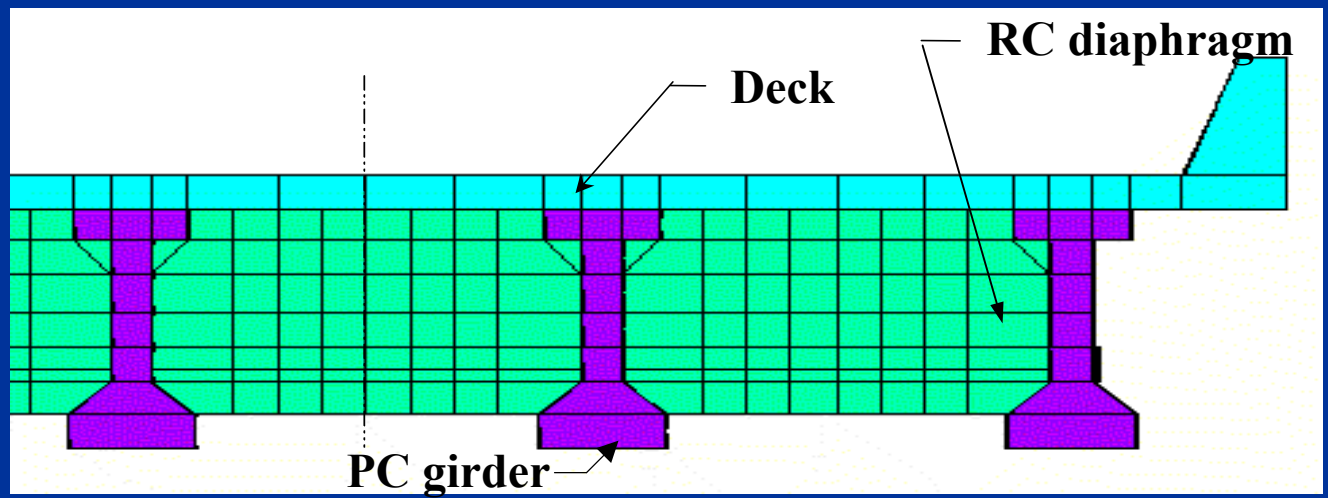

C.L. of expansion pier
97 ft - 0 in.
C.L. of fixed pier

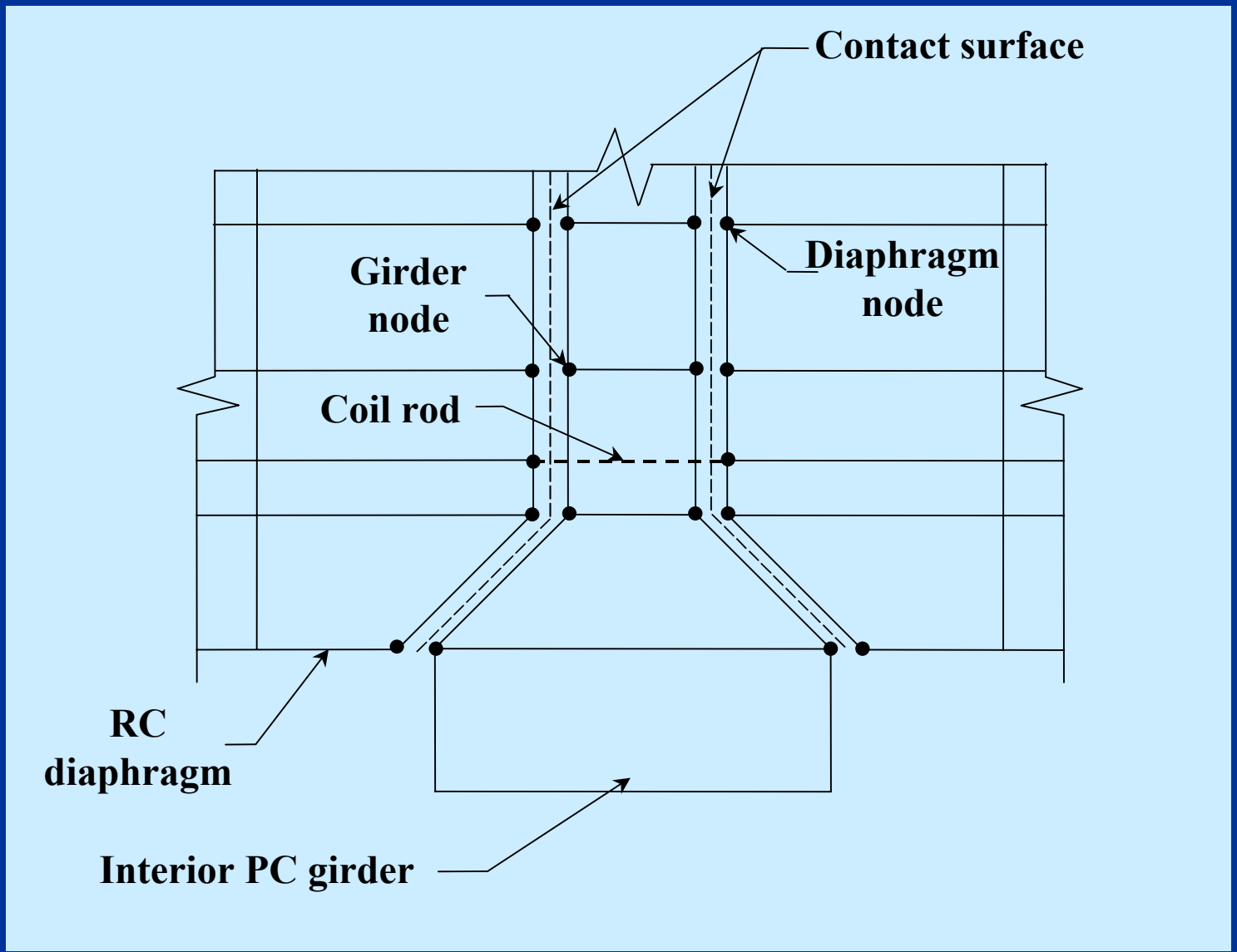

0.6
0.5
0.4
0.3
0.2
0.1
0
Displacement (in.)
4SPANS
1SPAN
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
Time (sec.)

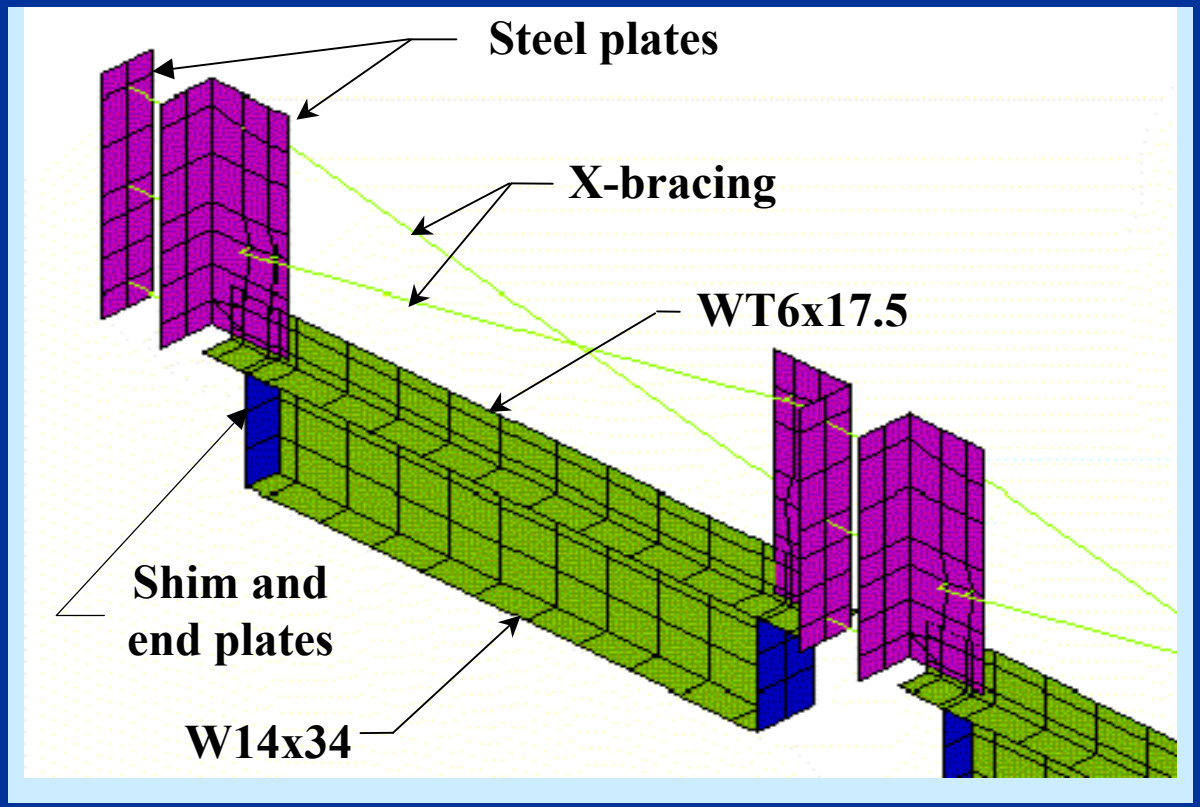

900
800
700
600
500
400
300
200
100
0
Micro-strain
0
0.05
0.1
0.15
Time (sec.)
4SPANS
1SPAN

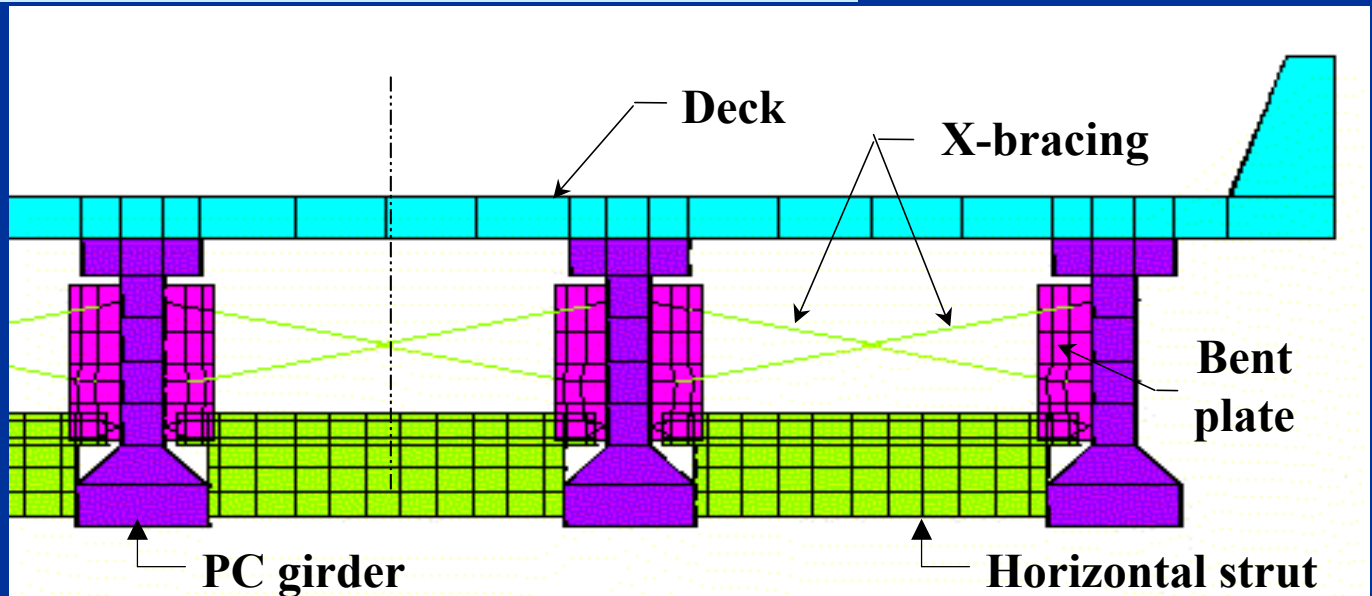
Intermediate Diaphragm Models

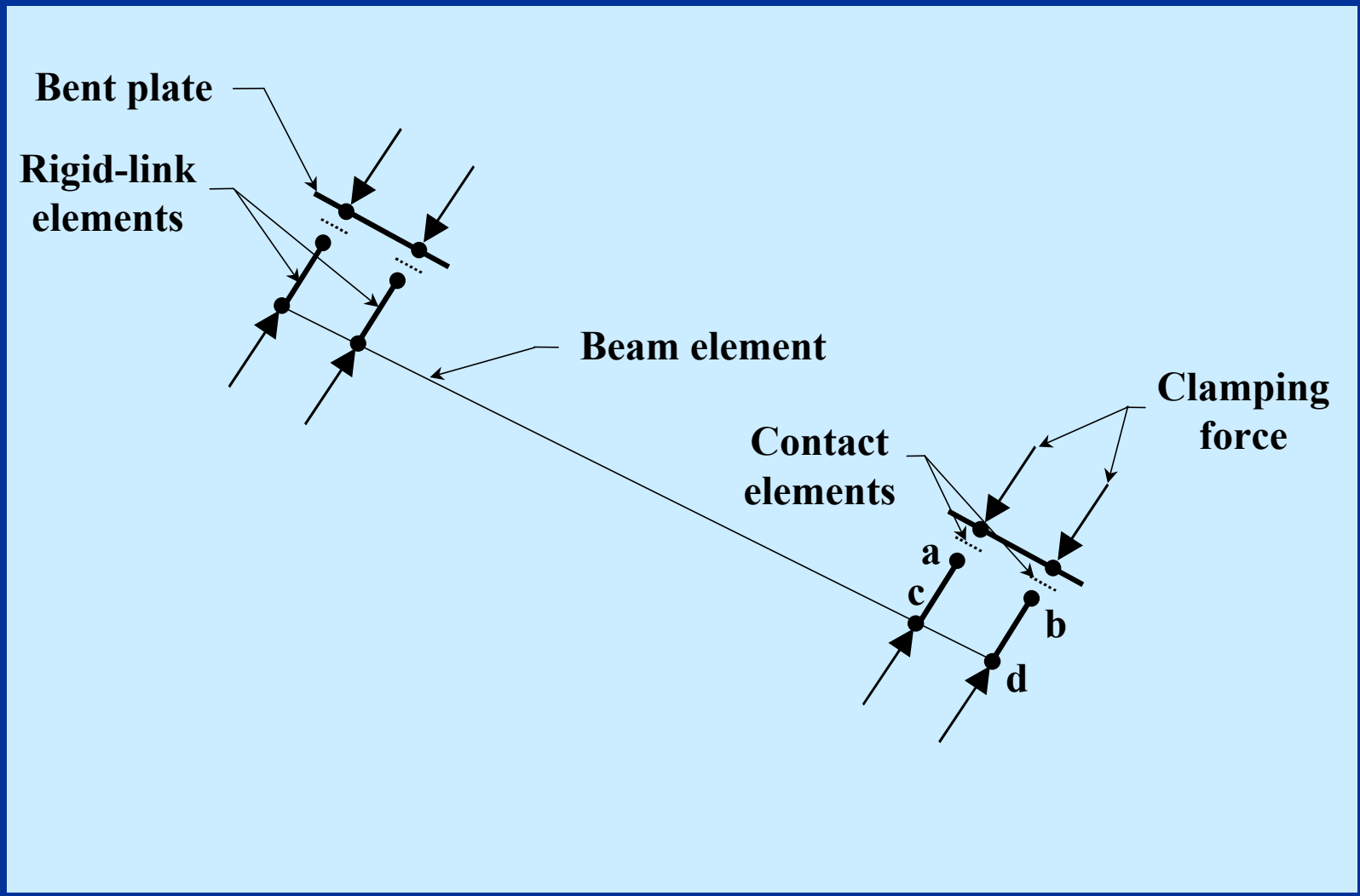



RC diaphragm
Deck
PC girder

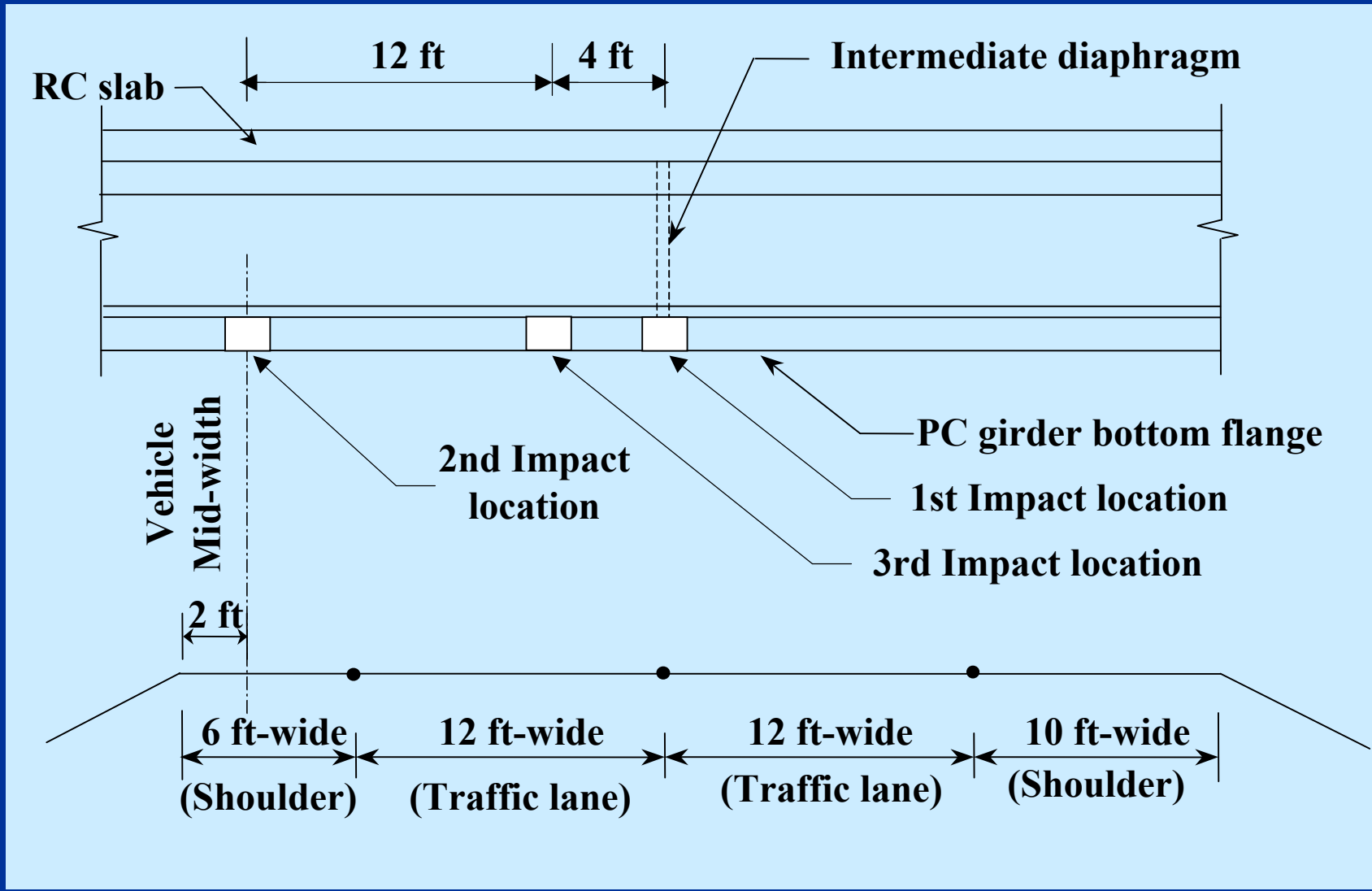

Contact surface
Girder node
Diaphragm node
Coil rod
RC diaphragm
Interior PC girder


Steel plates
X-bracing
WT6x17.5
Shim and
end plates
W14x34

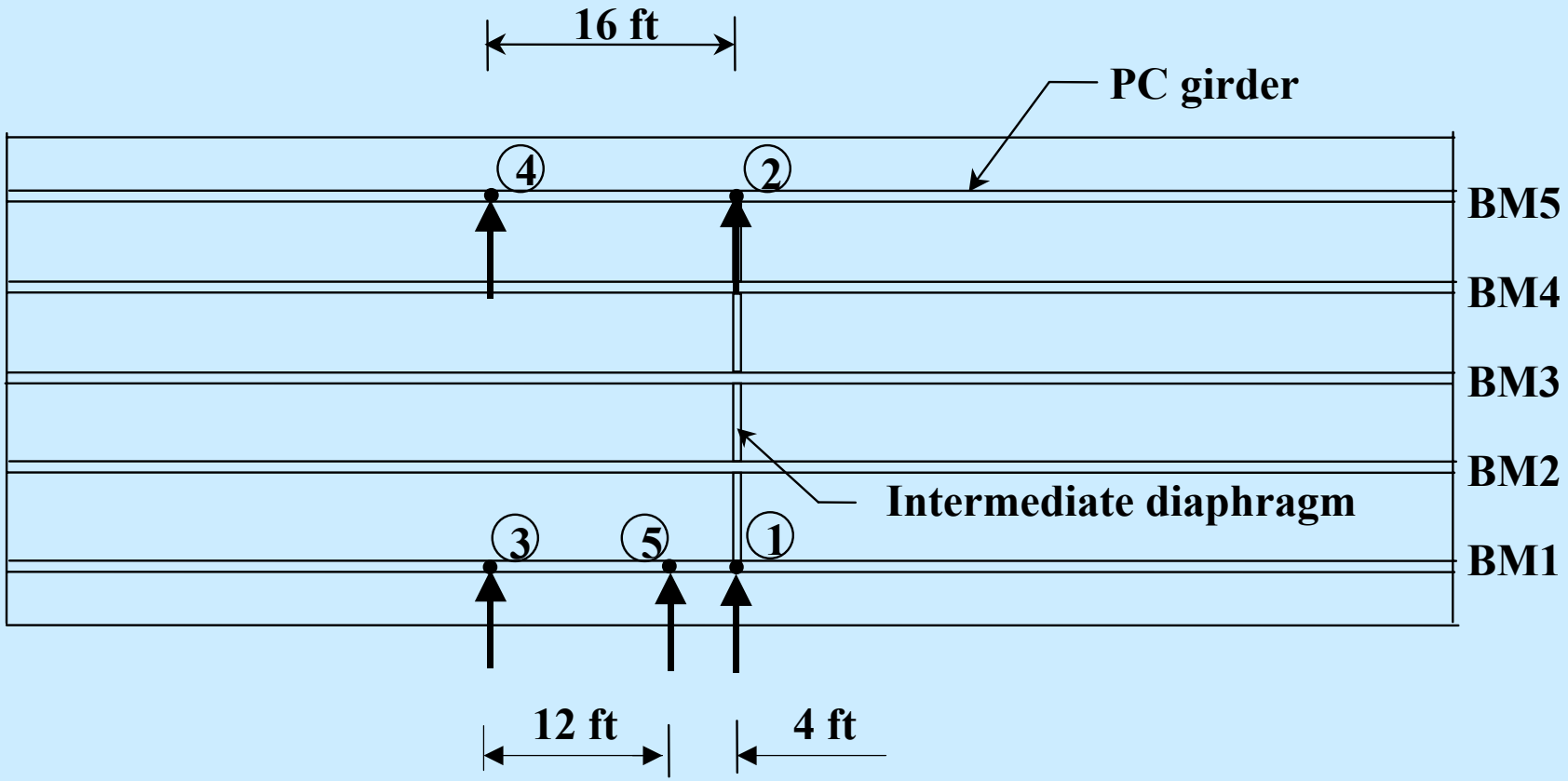

Deck
X-bracing
Bent
plate
PC girder
Horizontal strut


Bent plate
Rigid-link elements
Beam element
Contact elements
Clamping force
a
c
b
d

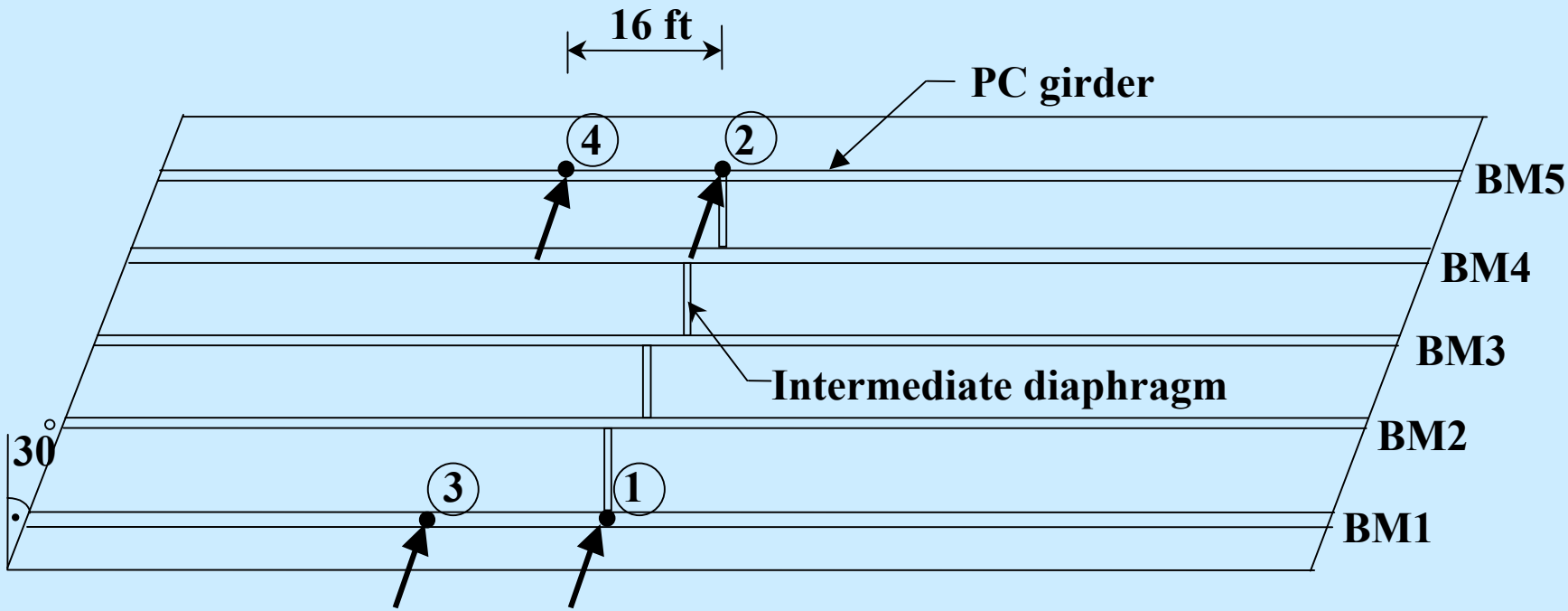
Load Points


12 ft
4 ft
RC slab
Intermediate diaphragm
Vehicle Mid-width
2nd Impact location
PC girder bottom flange
1st Impact location
3rd Impact location
2 ft
6 ft-wide (Shoulder)
12 ft-wide (Traffic lane)
12 ft-wide (Traffic lane)
10 ft-wide (Shoulder)

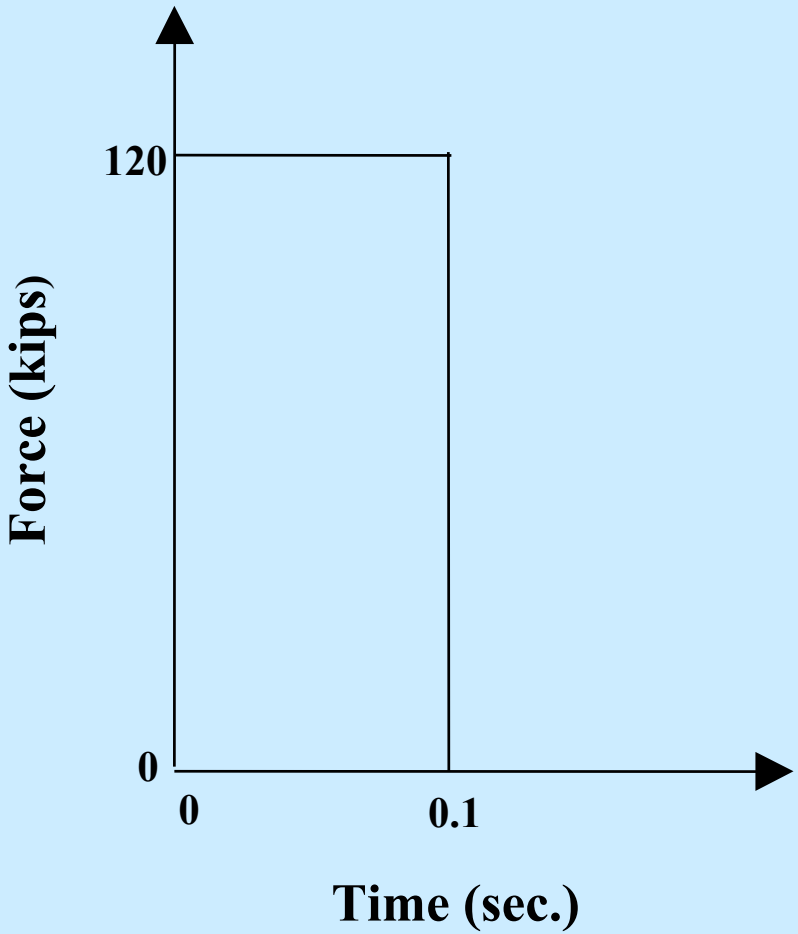
Load Points (cont'd.)

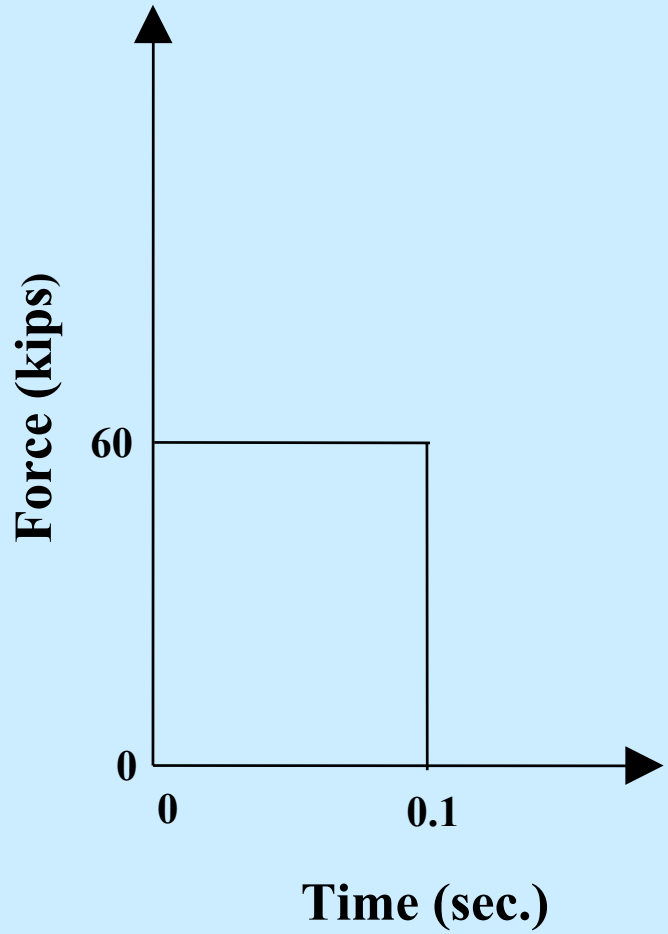


Load Points (cont'd.)

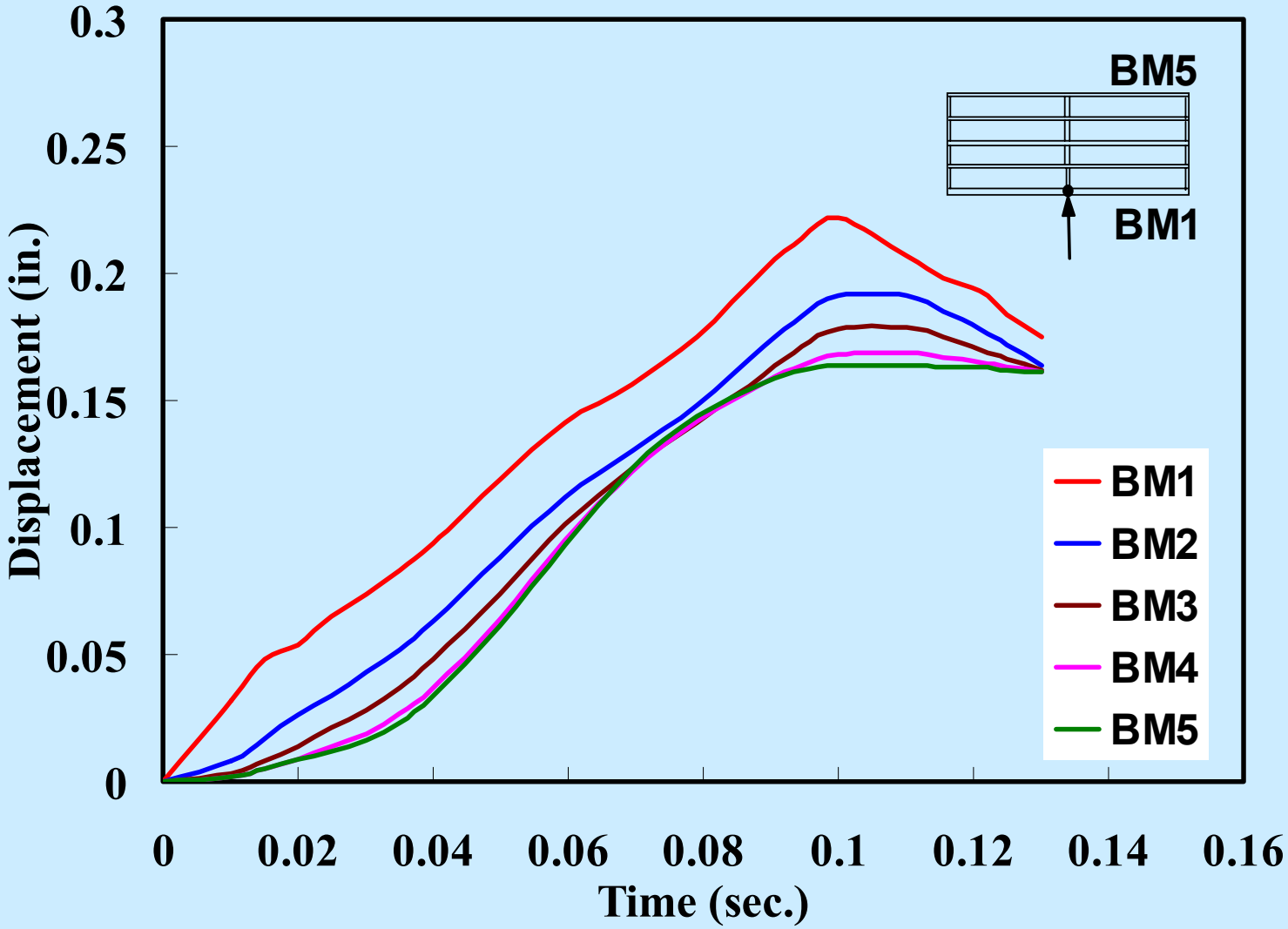


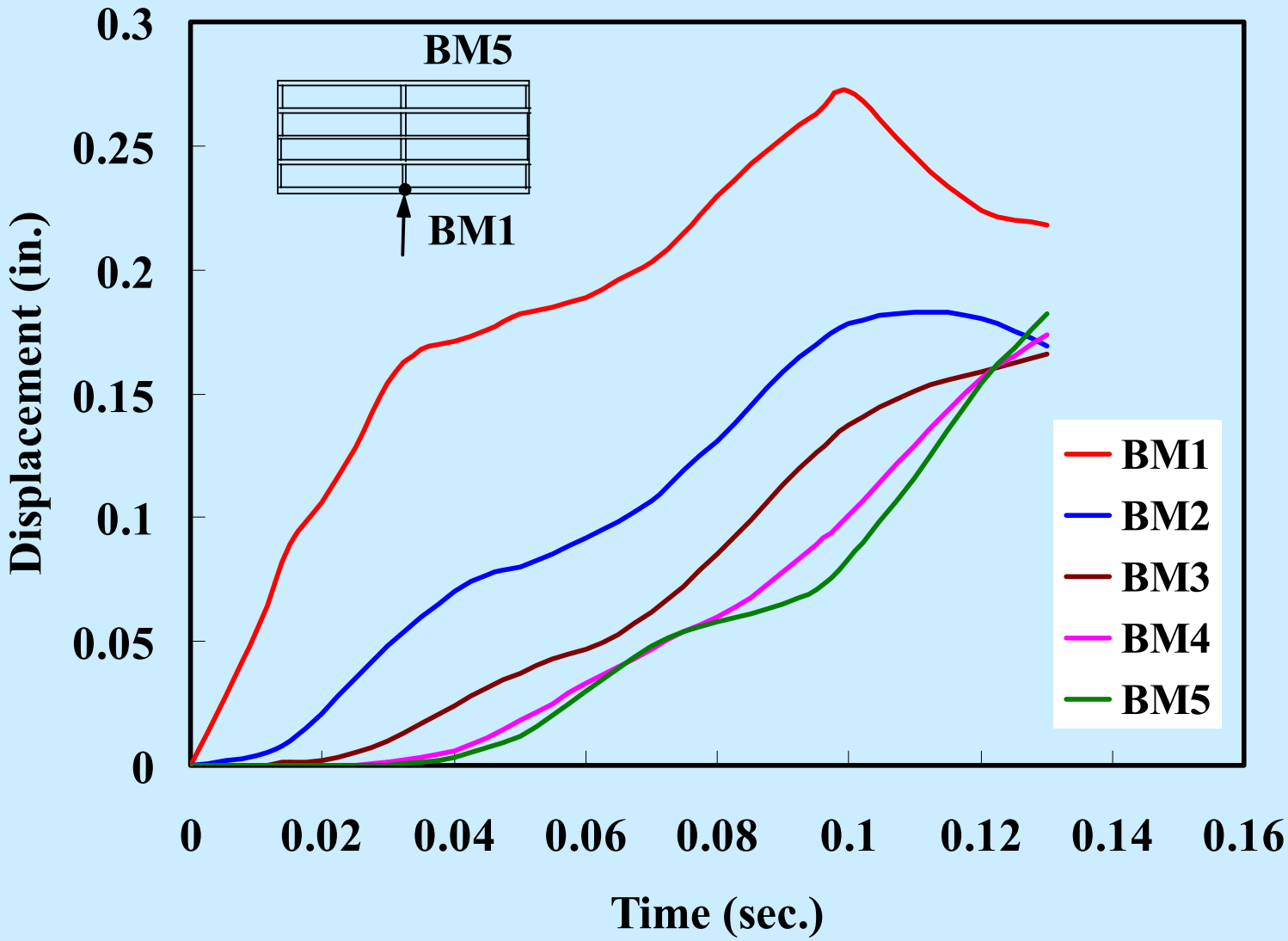
Load Magnitudes and Duration

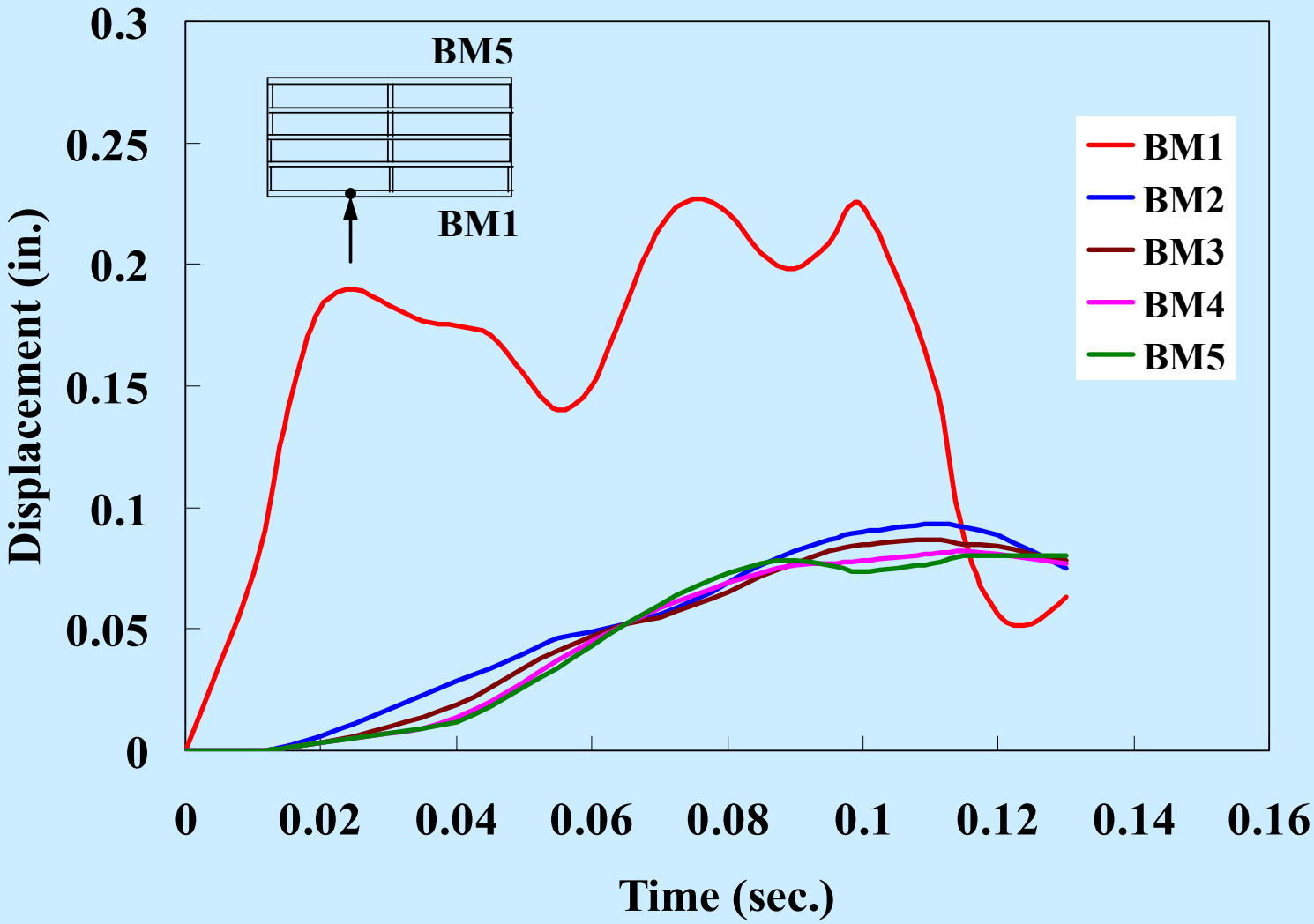


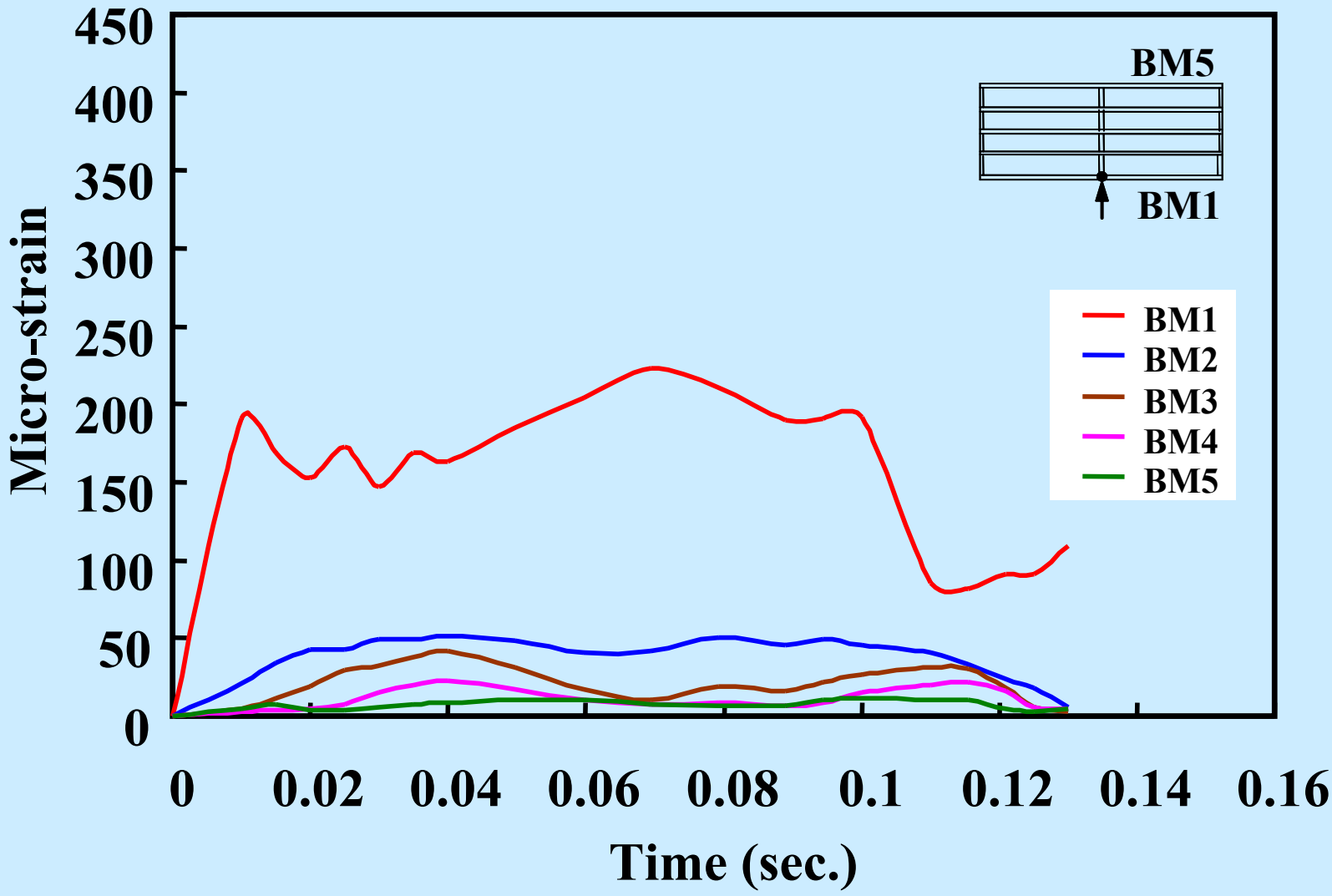


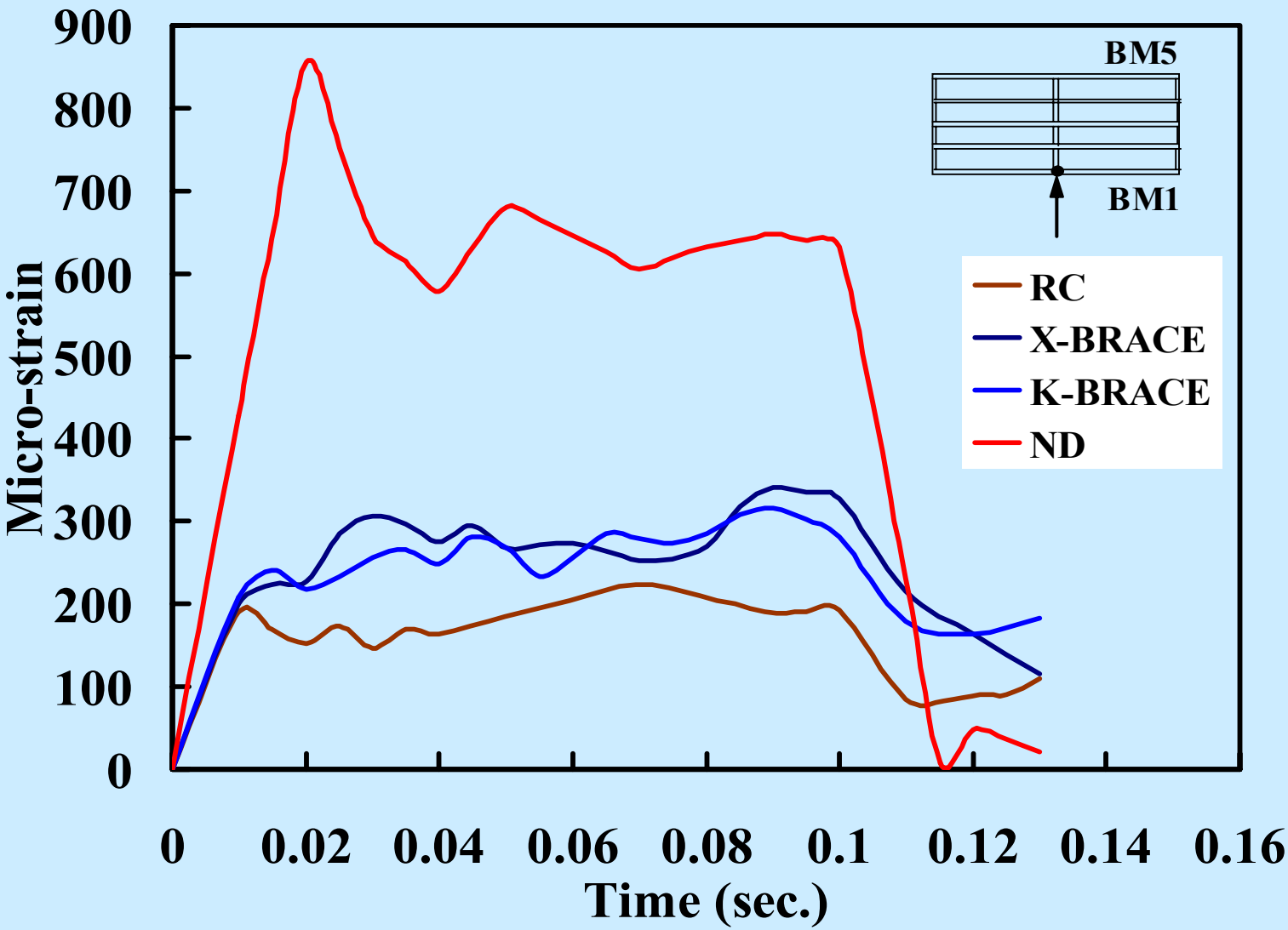
Analytical Results

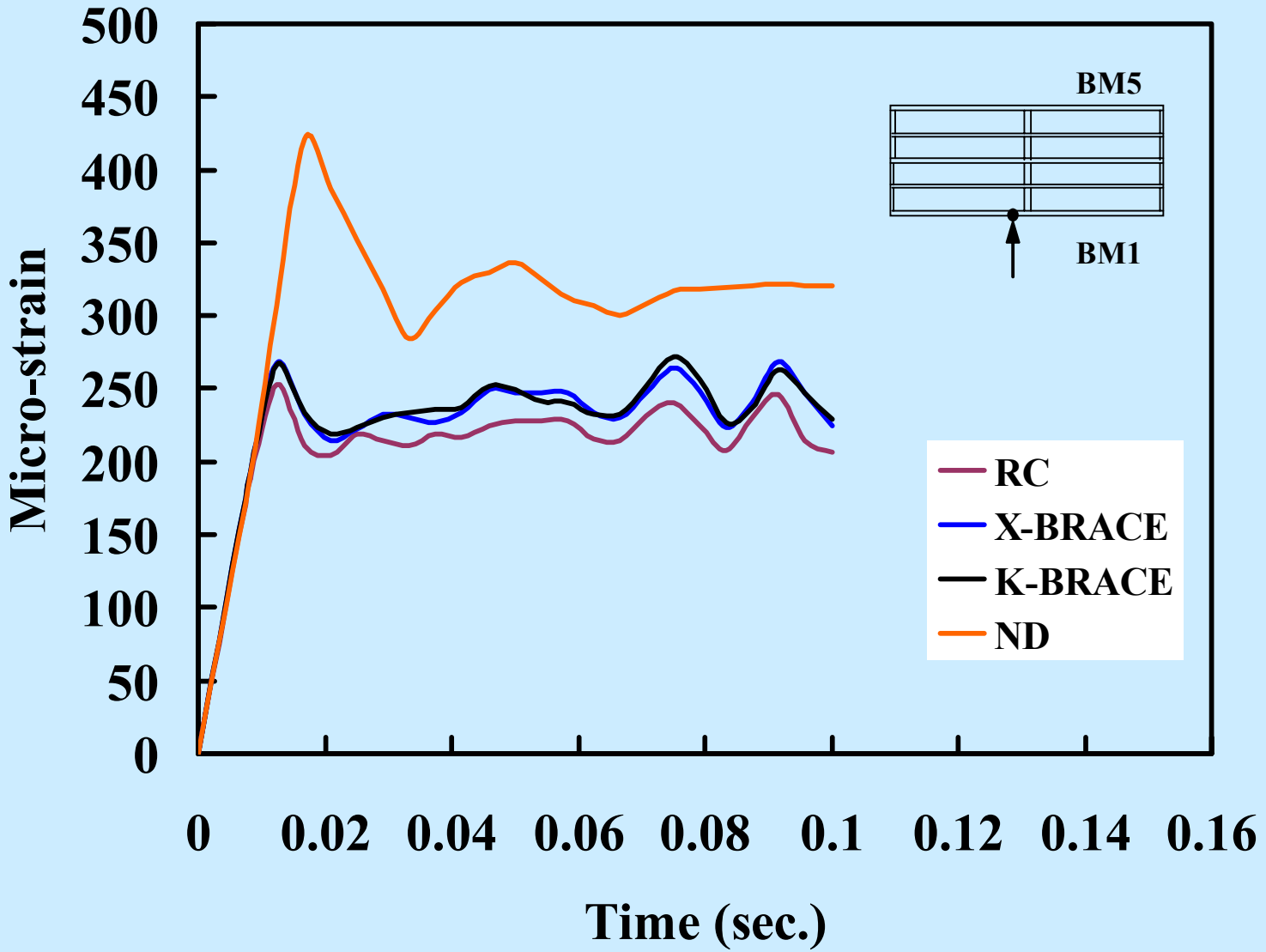

0.3
0.25
0.2
0.15
0.1
0.05
0
Displacement (in.)
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
Time (sec.)
BM5
BM1
BM1
BM2
BM3
BM4
BM5

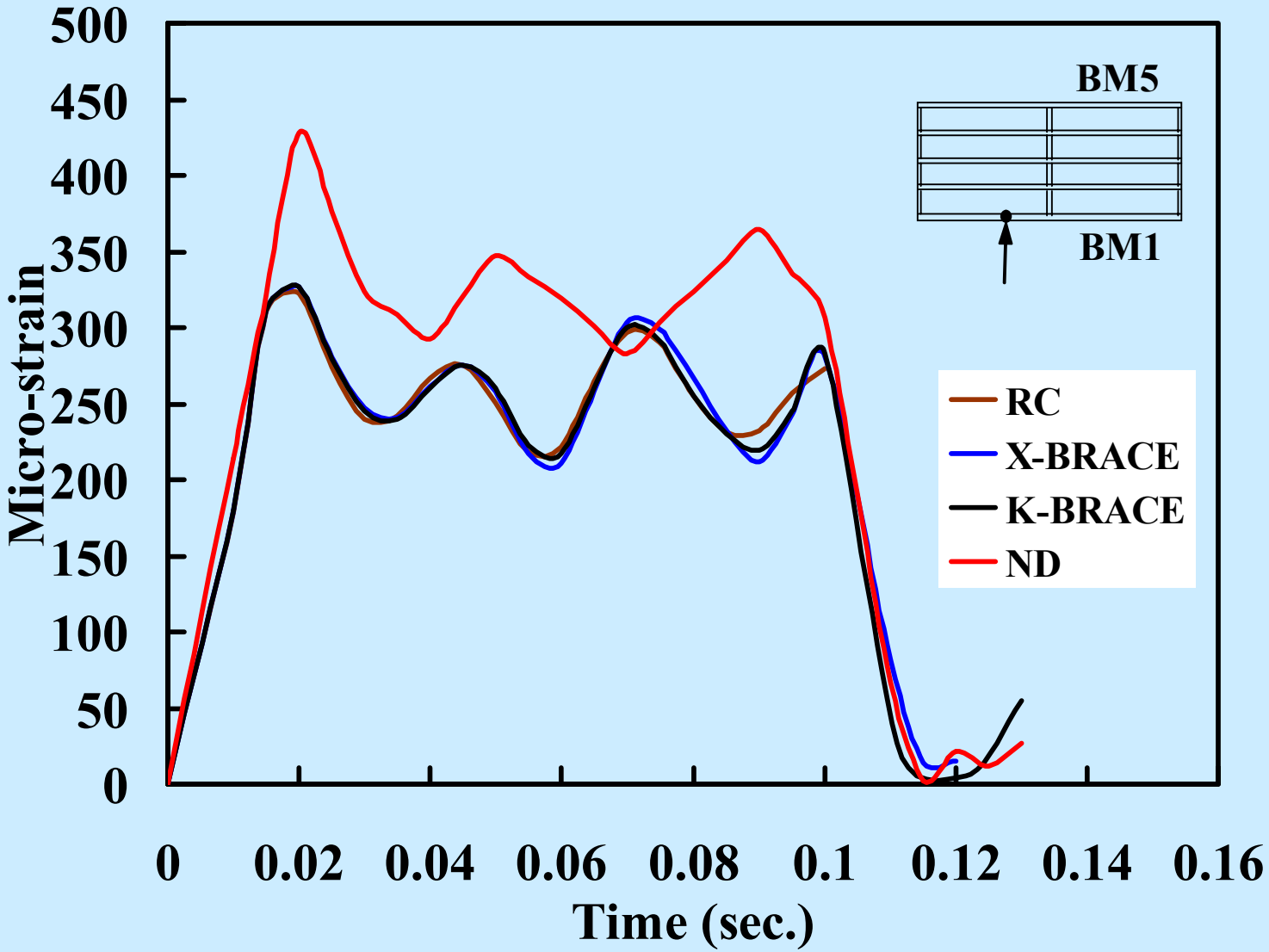

BM5
BM1
Displacement (in.)
0.3
0.25
0.2
0.15
0.1
0.05
0
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
Time (sec.)
BM1
BM2
BM3
BM4
BM5

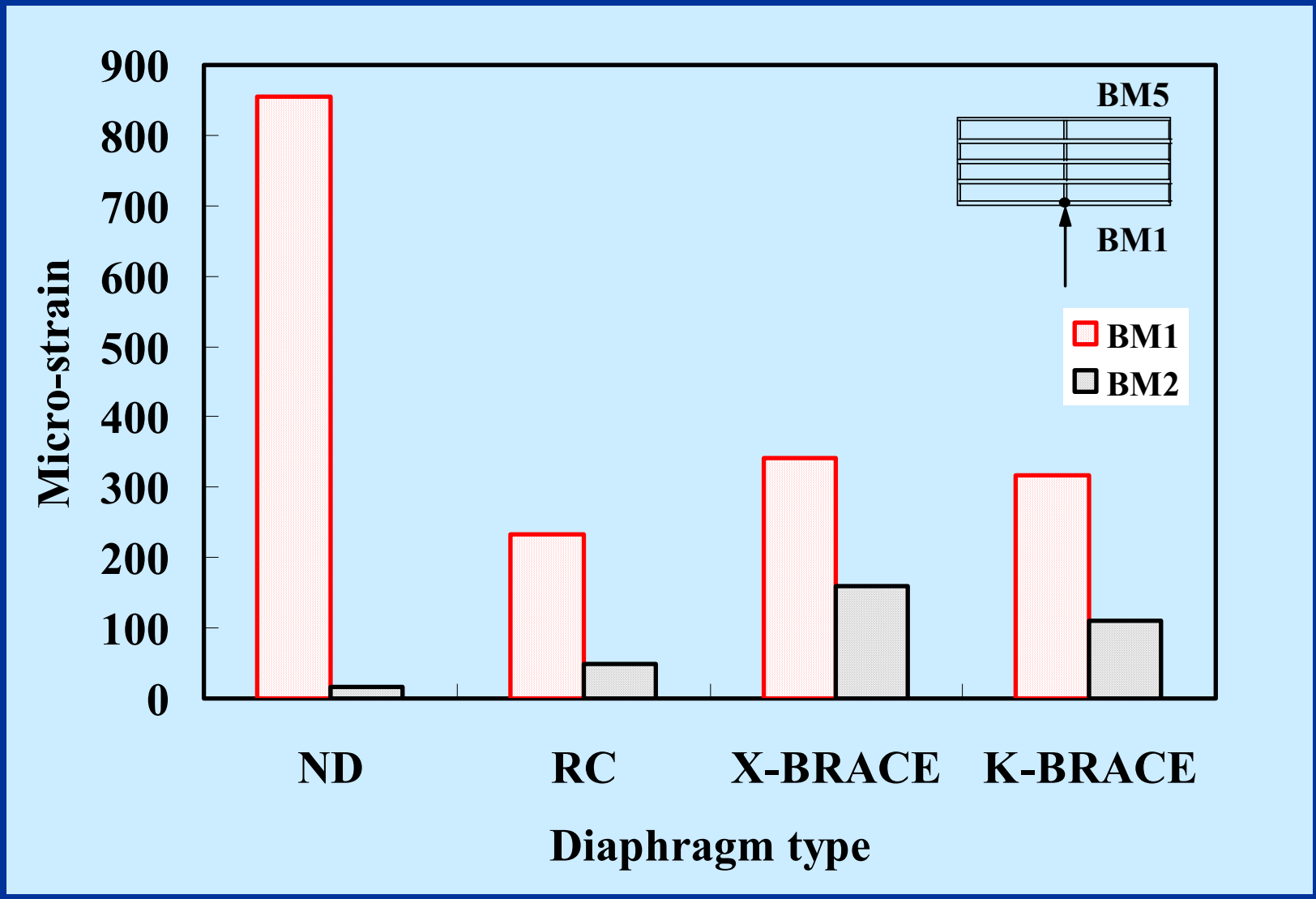

BM5
BM1
BM1
BM2
BM3
BM4
BM5
Displacement (in.)
0.3
0.25
0.2
0.15
0.1
0.05
0
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
Time (sec.)

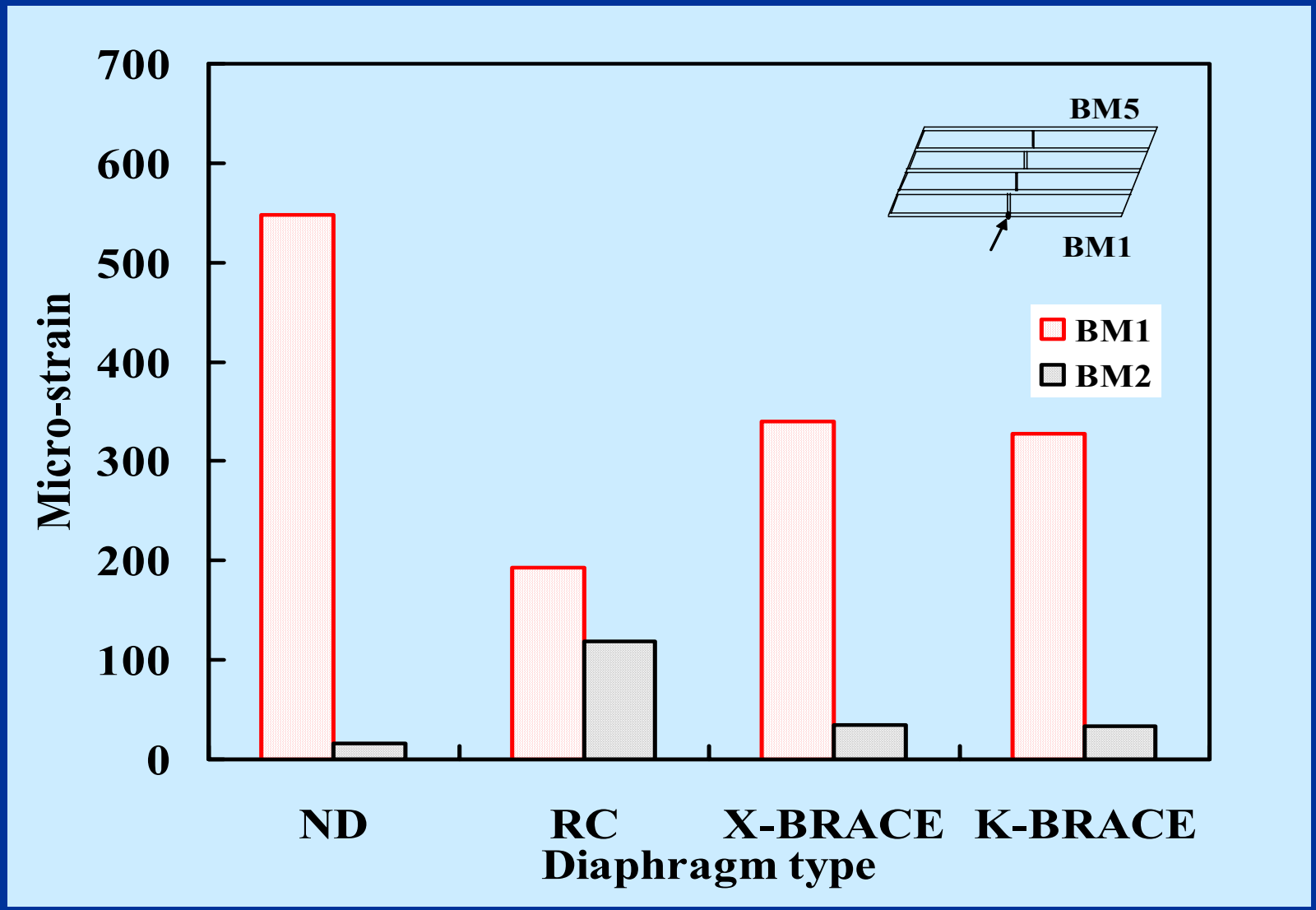

Micro-strain
450
400
350
300
250
200
150
100
50
0
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
Time (sec.)
BM5
BM1
BM1
BM2
BM3
BM4
BM5

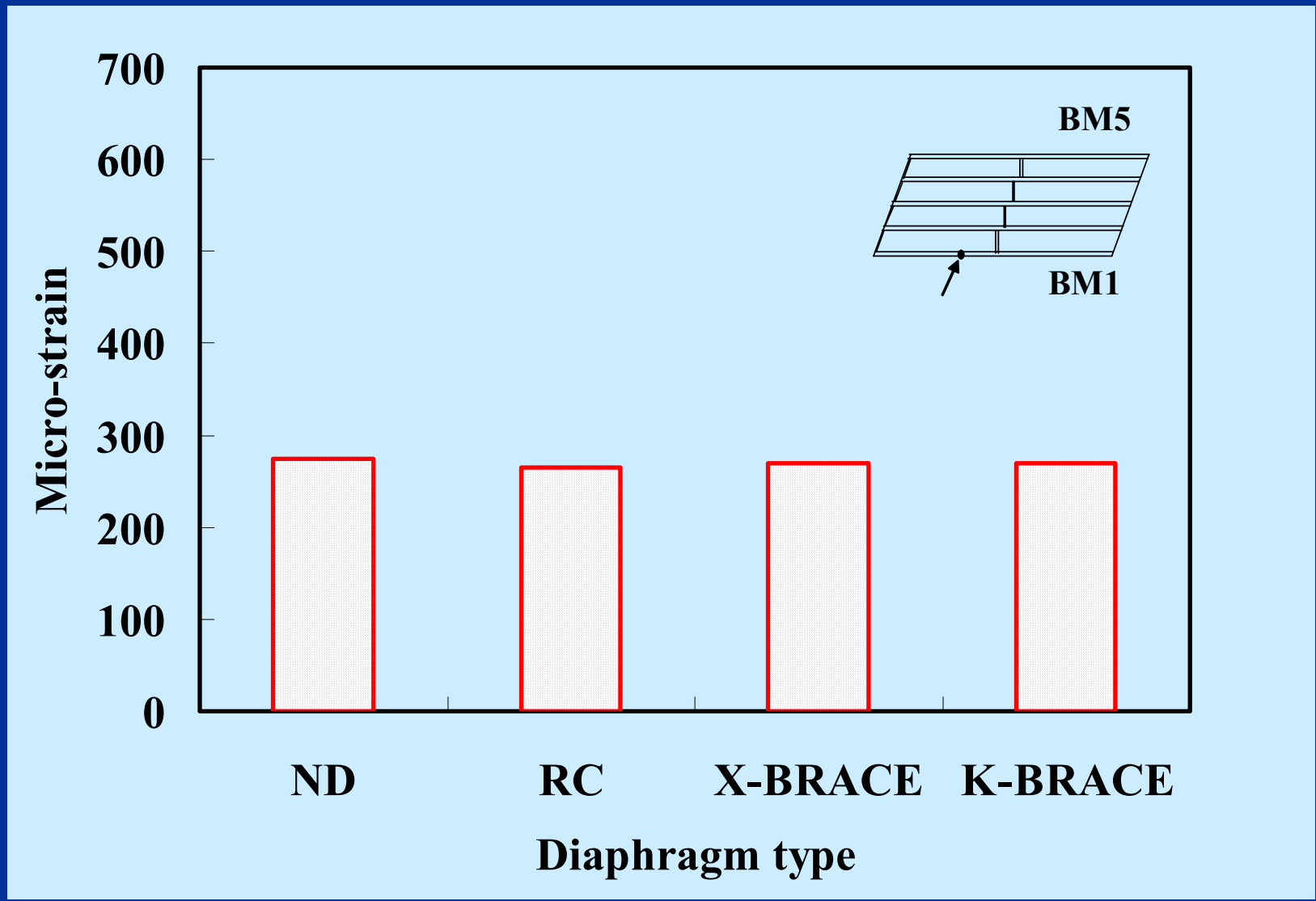

900
800
700
600
500
400
300
200
100
0
Micro-strain
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
Time (sec.)
BM5
BM1
RC
X-BRACE
K-BRACE
ND


500
450
400
350
300
250
200
150
100
50
0
Micro-strain
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
Time (sec.)
BM5
BM1
RC
X-BRACE
K-BRACE
ND


500
450
400
350
300
250
200
150
100
50
0
Micro-strain
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
Time (sec.)
BM5
BM1
RC
X-BRACE
K-BRACE
ND


900
800
700
600
500
400
300
200
100
0
Micro-strain
BM5
BM1
BM1
BM2
ND
RC
X-BRACE
K-BRACE
Diaphragm type


700
600
500
400
300
200
100
0
Micro-strain
BM5
BM1
BM1
BM2
ND
RC
X-BRACE
K-BRACE
Diaphragm type


700
600
500
400
300
200
100
0
Micro-strain
BM5
BM1
ND
RC
X-BRACE
K-BRACE
Diaphragm type

Conclusions

- Impacted girder in non-skewed and skewed bridges
  - Impact at the diaphragm

    RC induced the smallest tensile strains.
  - Impact not at the diaphragm (most likely)

    All diaphragms induced similar tensile strains.

Conclusions (cont'd.)

- Girder adjacent to the impacted girder.
  - Impact at the diaphragm in a non-skewed bridge.

    Steel induced higher tensile strains.
  - Impact at the diaphragm in a skewed bridge.

    RC induced higher tensile strains.