American Concrete Institute

# EFFECT OF SHEAR SPAN TO DEPTH RATIO ON THE BEHAVIOR OF RAC BEAMS

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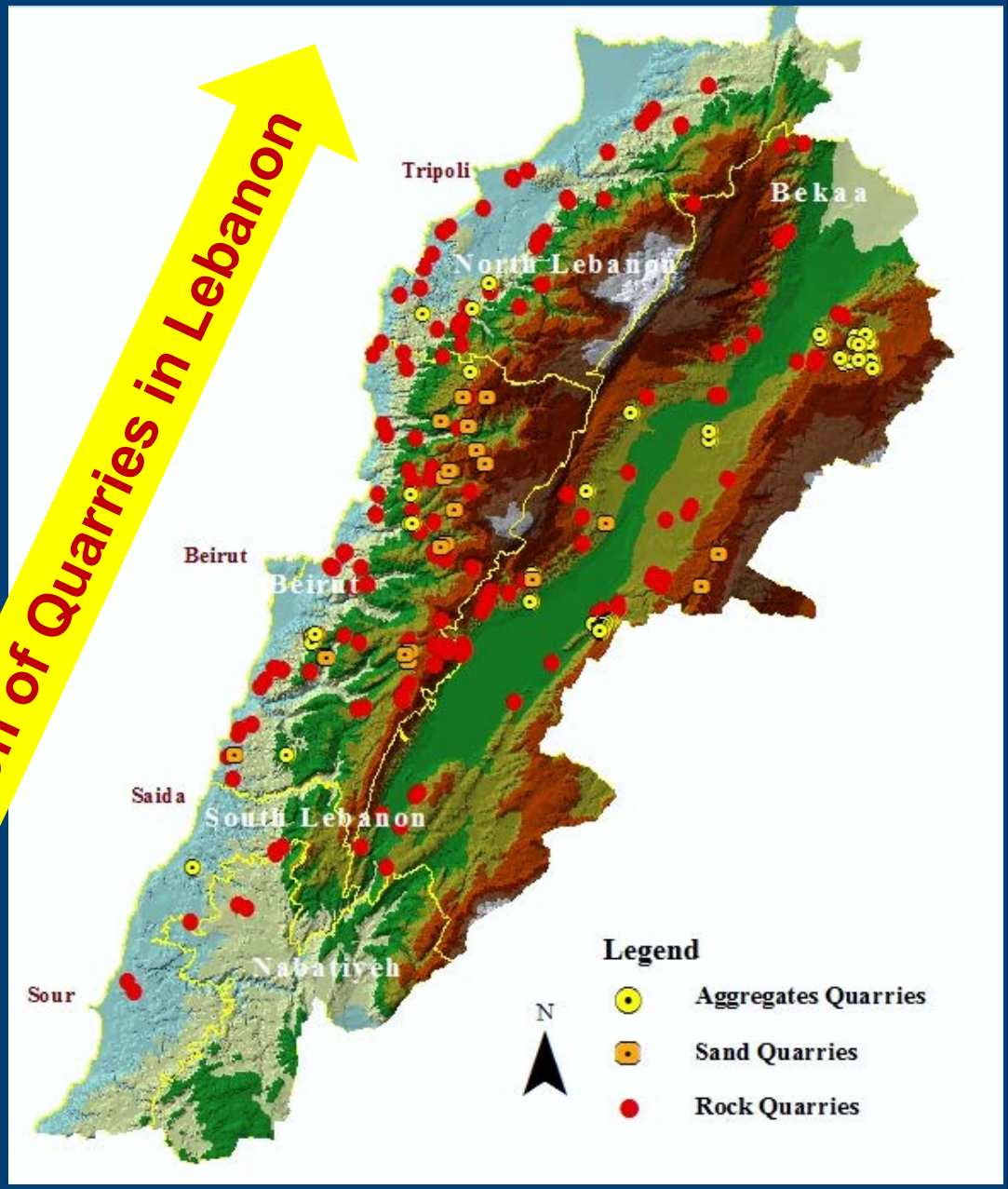
# OUTLINE

- Research Motivation
- Objectives
- Experimental Program
  - Test Beams
  - Materials & Mix Design
  - Instrumentation and Test Setup
- Experimental Results & Discussion
- Conclusions

# RESEARCH MOTIVATION

Chekka Quarry in the vicinity of UOB



# OBJECTIVES

The objective of this research is to study the effect of shear span to depth ratio on the shear behavior of Recycled Aggregates Concrete (RAC) beams.

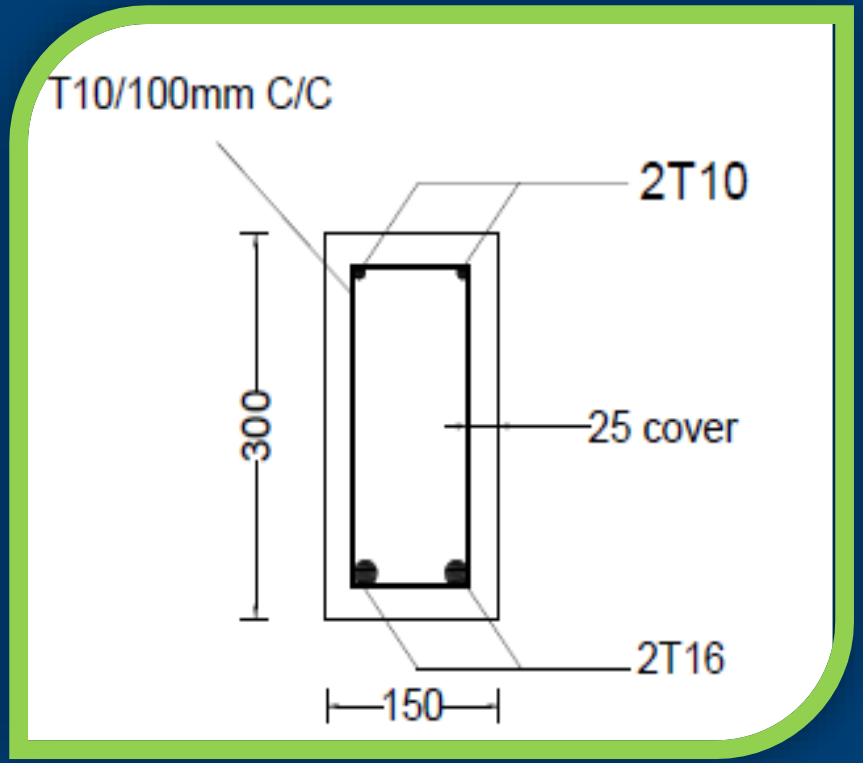
# EXPERIMENTAL PROGRAM

- Nine beams were designed to fail in shear
- Three values for shear span to depth ratio were selected: 2.5, 3.5 and 4.
- Five beams were made with 100% [R100] recycled concrete aggregates [a/d: 2.5, 3.5 and 4].
- Two beams [a/d: 3.5 & 4] were made with 50% [R50] recycled concrete aggregates.
- Two beams [a/d: 3.5 & 4] [R0] were made with natural aggregates.

# TEST BEAMS

- All beams were 3 m long with 2.7 m span length
- All beams were reinforced with 2T16 at the bottom and 2T10 at the top giving $\rho=1.04\%$
- Shear reinforcement in the form of vertical stirrups was omitted.
- All beams had the same  cross section 150 by 300 mm.
- Variables are: shear span to depth ratio for two levels of coarse aggregates replacement 50% and 100%.
- The beams were subjected to four point loading test.
- Beams' deflection, crack patterns, ultimate shear capacity; and failure modes are all observed and analyzed.

# Beams' Cross-Section



# MATERIALS AND MIX PROPORTIONS

- The recycled concrete aggregates were obtained by crushing the control specimens tested at UOB civil engineering laboratory.
- All coarse aggregates were sieved into two sizes: coarse (9.5–19 mm) and medium (4.75–9.5 mm).
- Table 1 summarizes the test results on the physical properties of natural and recycled aggregates.

# TABLE 1: PHYSICAL PROPERTIES OF NATURAL AND RECYCLED AGGREGATES

| Aggregates | NCA (4.75-9.5) mm | RCA (4.75-9.5) mm | NCA (9.5-19) mm | RCA (9.5-19) mm |
|---|---|---|---|---|
| SSD (Saturated Surface Dry) | 2.654 | 2.415 | 2.676 | 2.290 |
| Apparent SG | 2.706 | 2.688 | 2.713 | 2.457 |
| OD (Oven-Dry) SG | 2.623 | 2.253 | 2.653 | 2.175 |
| Absorption (%) | 1.171 | 7.189 | 0.835 | 5.273 |
| Bulk density kg/m³ | 1525 | 1305 | 1552 | 1359 |

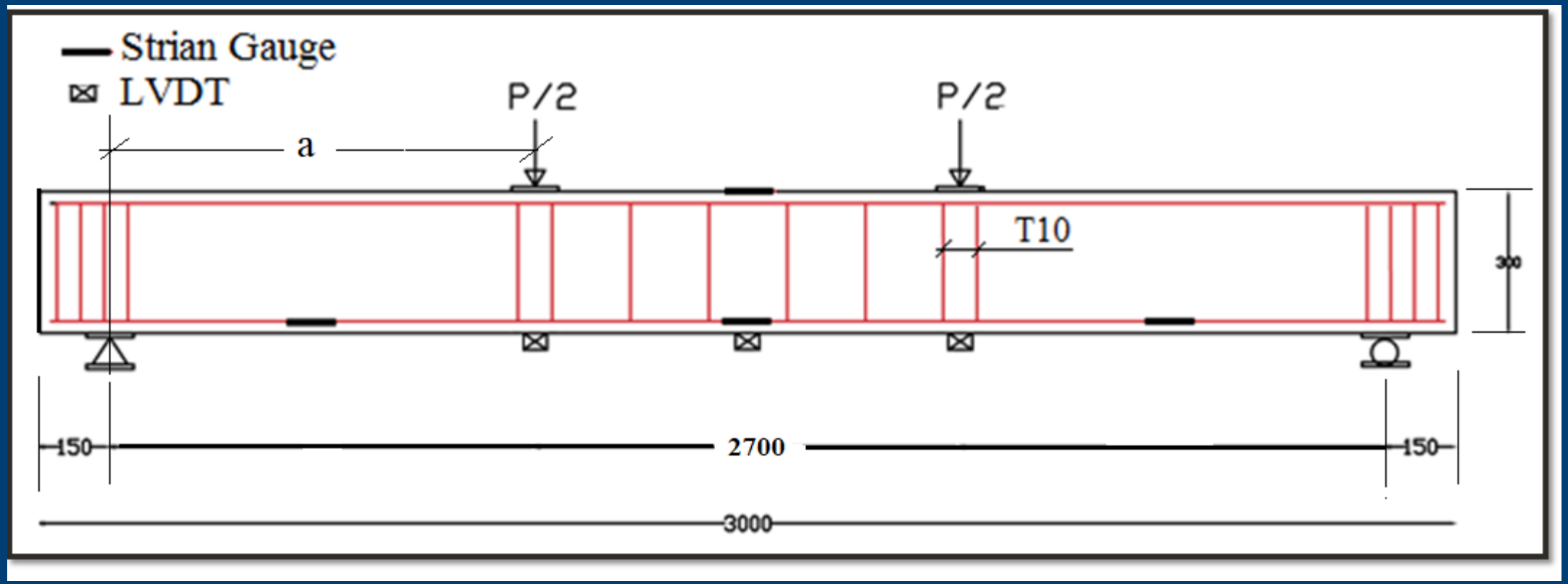
# MIX DESIGN

- Table 2 illustrates the mix design used throughout this study.
- Only coarse aggregates were replaced by recycled concrete aggregates.
- All constituent materials were oven dried for 24 hours before casting at 110±5 ºC.
- The water compensation method was used.

# TABLE 2: Mix design

| Mix | Cement | NCA 4.75-9.5 mm | NCA 9.5-19 mm | RCA 4.75-9.5 mm | RCA 9.5-19 mm | Natural sand | Free water |
|---|---|---|---|---|---|---|---|
| | (kg/m³) | (kg/m³) | (kg/m³) | (kg/m³) | (kg/m³) | (kg/m³) | (kg/m³) |
| **R0** | 350 | 444 | 666 | 0 | 0 | 741 | 178 |
| **R50** | 350 | 222 | 333 | 207 | 393 | 741 | 178 |
| **R100** | 350 | 0 | 0 | 400 | 610 | 741 | 178 |

# INSTRUMENTATION AND TEST SETUP



# EXPERIMENTAL RESULTS AND DISCUSSION

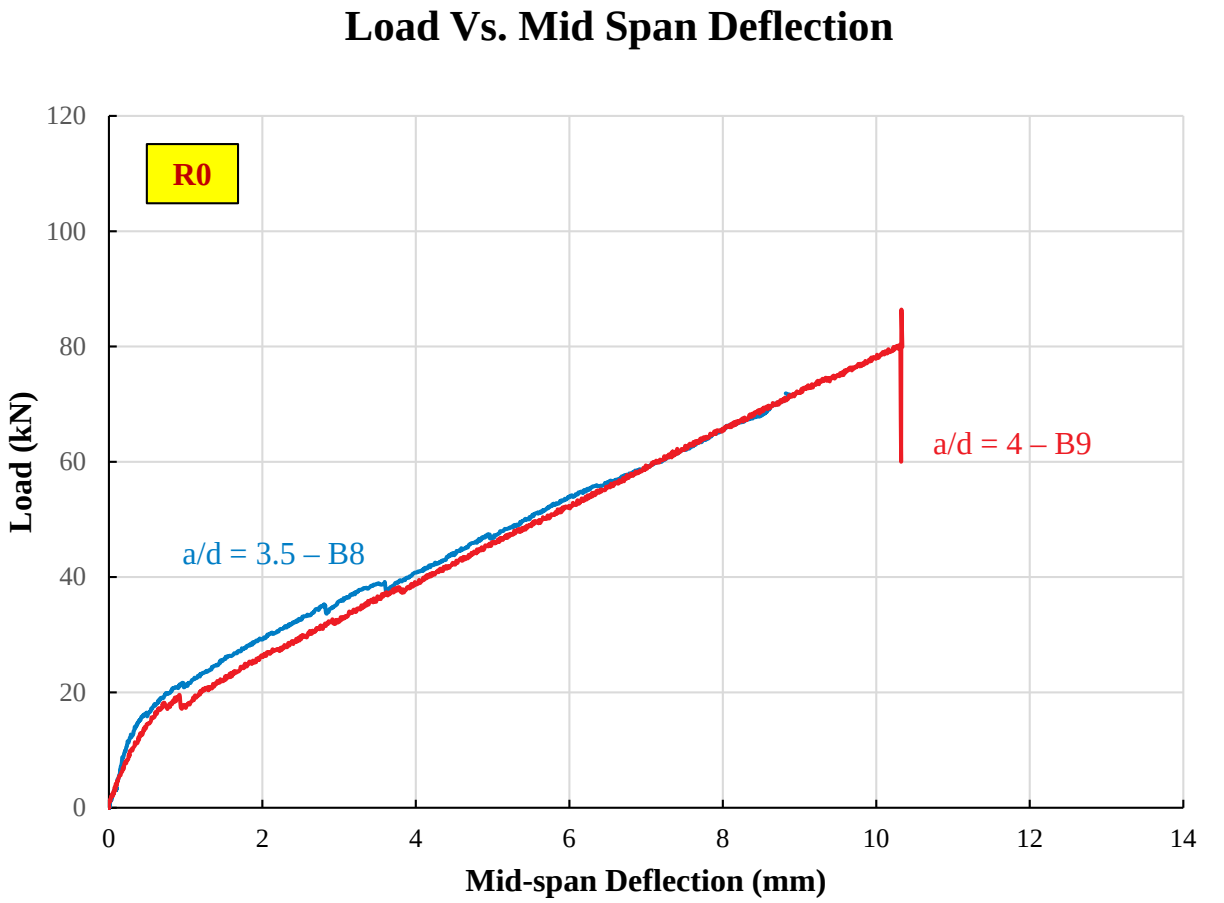
# MECHANICAL PROPERTIES

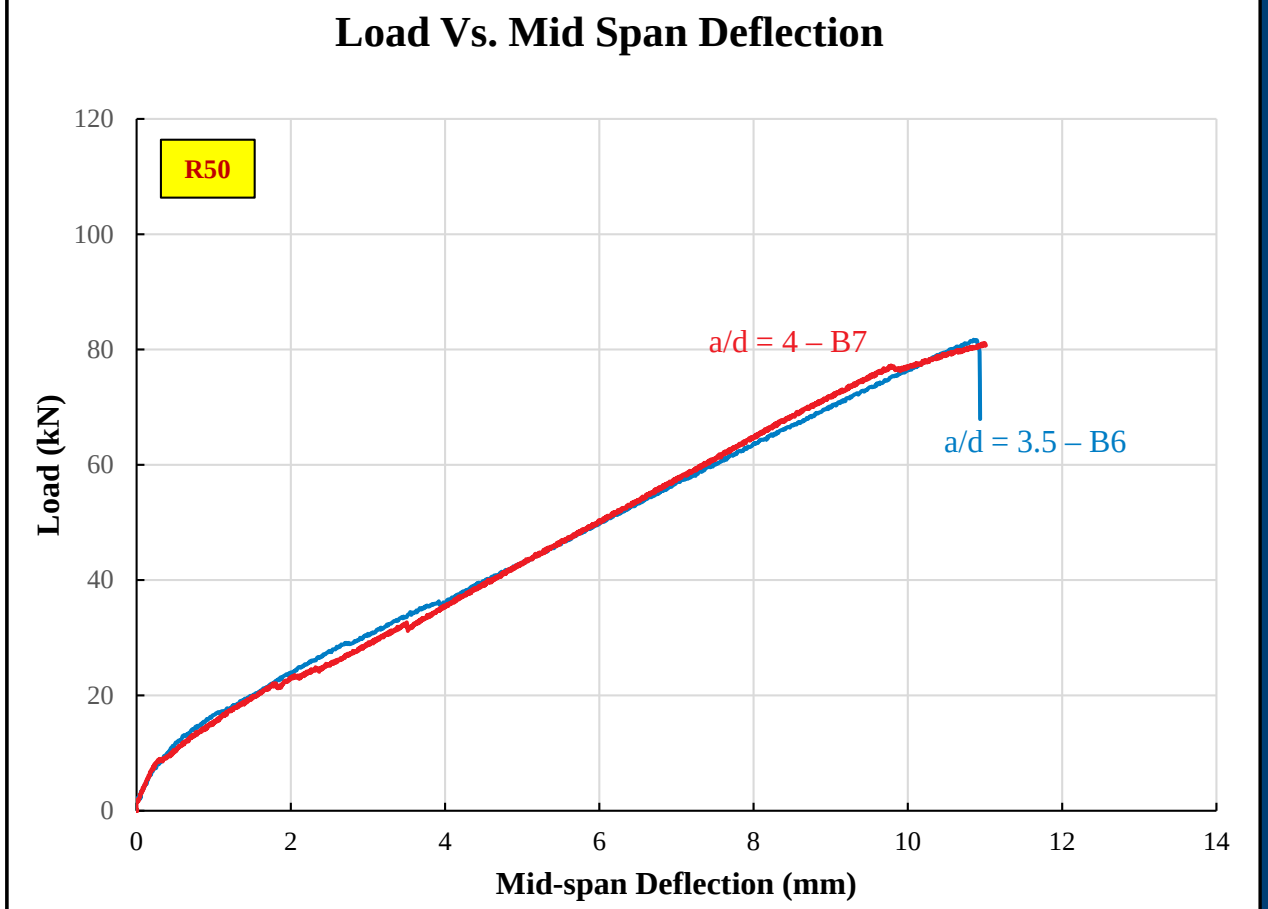
| Beam | RCA % | a/d | $f'_c$ | Ec | fsp | fr |
|---|---|---|---|---|---|---|
| | | | (MPa) | (MPa) | (MPa) | (MPa) |
| B1 | 100 | 2.5 | 37.65 | 25663 | 3.31 | 3.34 |
| B2 | 100 | 3.5 | 35.55 | 29,426 | 3.87 | 3.07 |
| B3 | 100 | 3.5 | 33.22 | 22729 | 2.43 | 3.95 |
| B4 | 100 | 4 | 27.72 | 26452 | 2.86 | 3.03 |
| B5 | 100 | 4 | 25.36 | 29426 | 2.92 | 4.17 |

# MECHANICAL PROPERTIES

| Beam | RCA % | a/d | $f'_c$ | Ec | fsp | fr |
|---|---|---|---|---|---|---|
| | | | (MPa) | (MPa) | (MPa) | (MPa) |
| B6 | 50 | 3.5 | 37 | 32521 | 3.66 | 3.07 |
| B7 | 50 | 4 | 41.53 | 32521 | 3.87 | 5.18 |
| B8 | 0 | 3.5 | 31.61 | 32486 | 3.9 | 3.97 |
| B9 | 0 | 4 | 38.25 | 32486 | 3.79 | 5.11 |

# LOAD VS MID-SPAN DEFLECTIONS

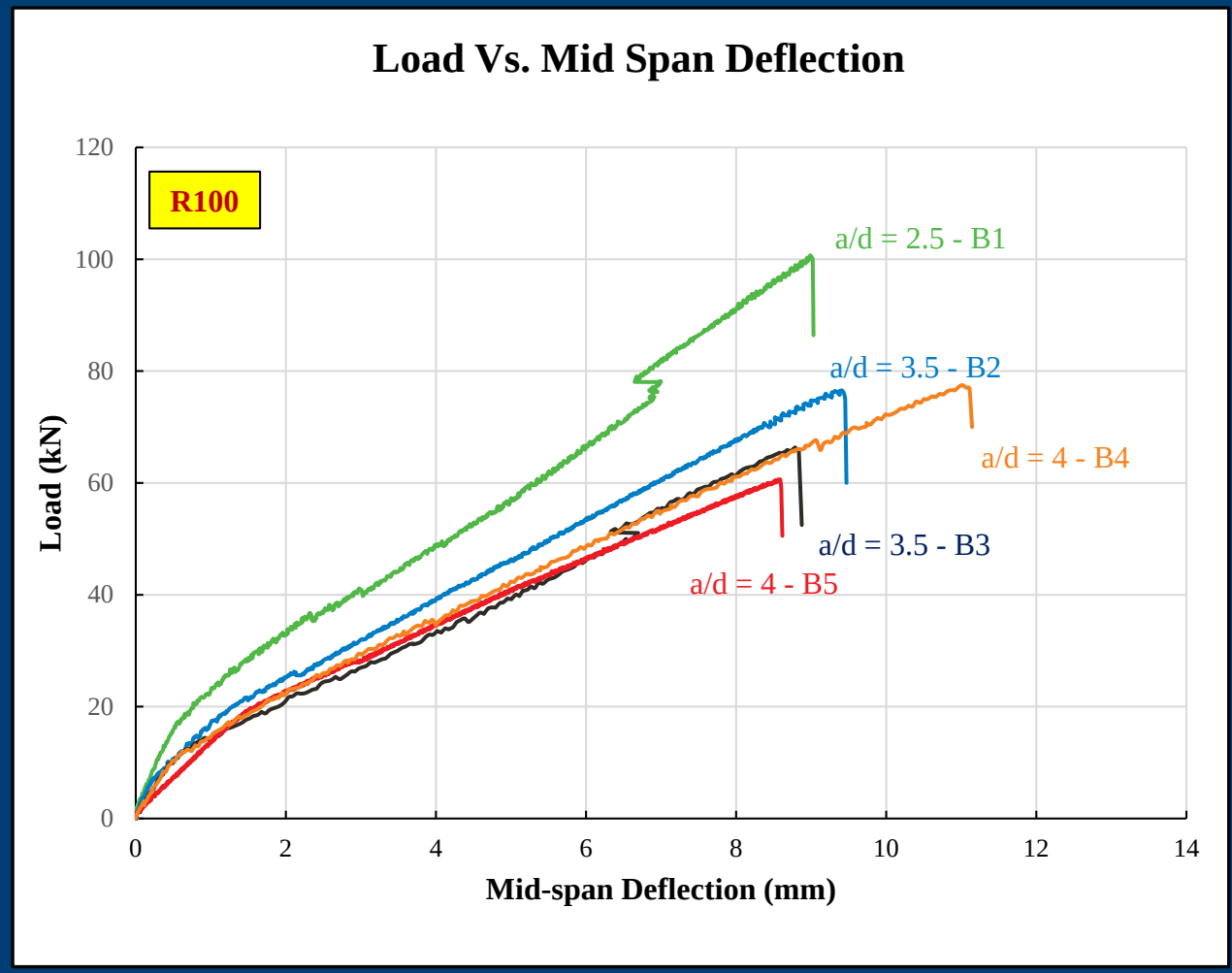


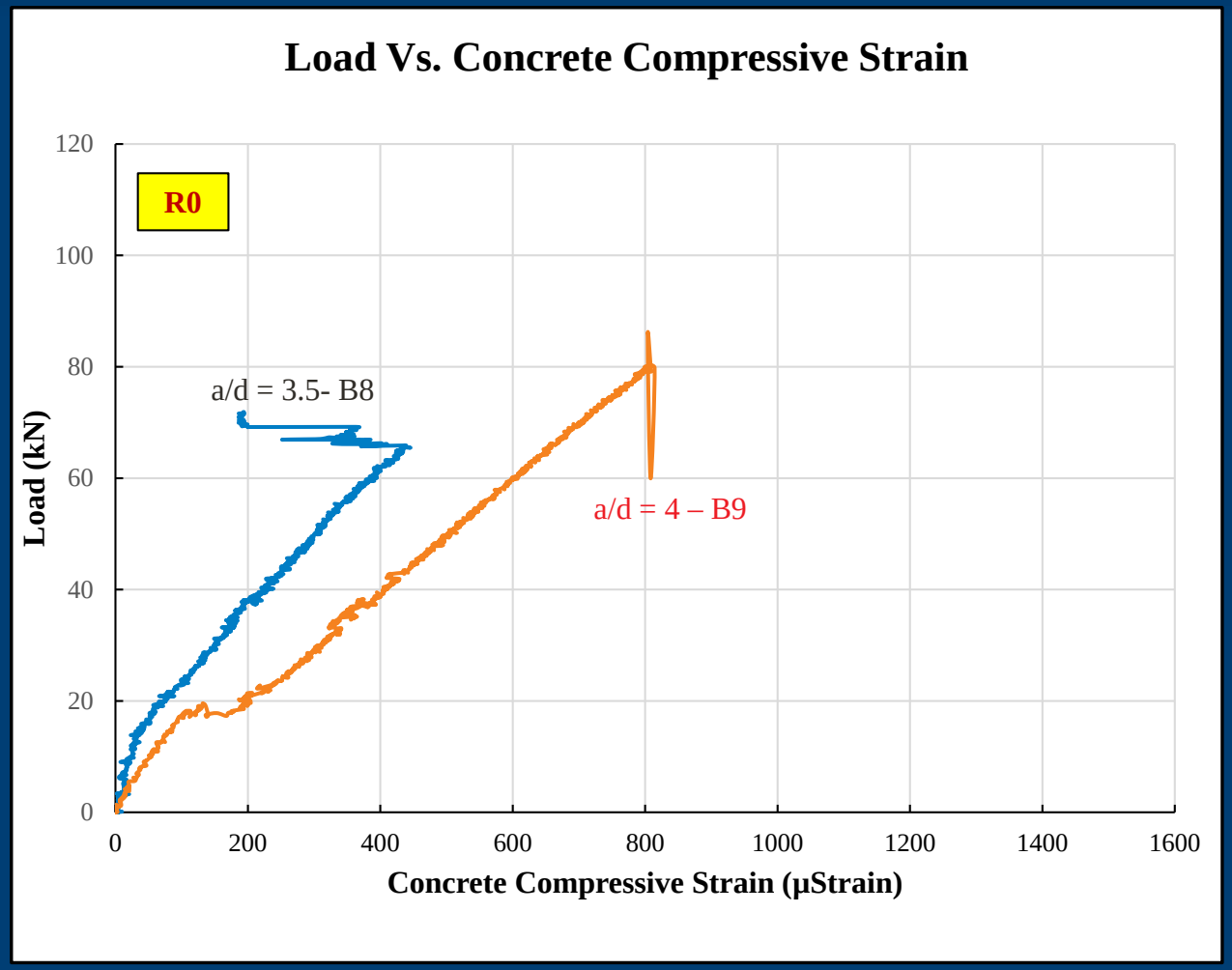
# LOAD VS MID-SPAN DEFLECTIONS

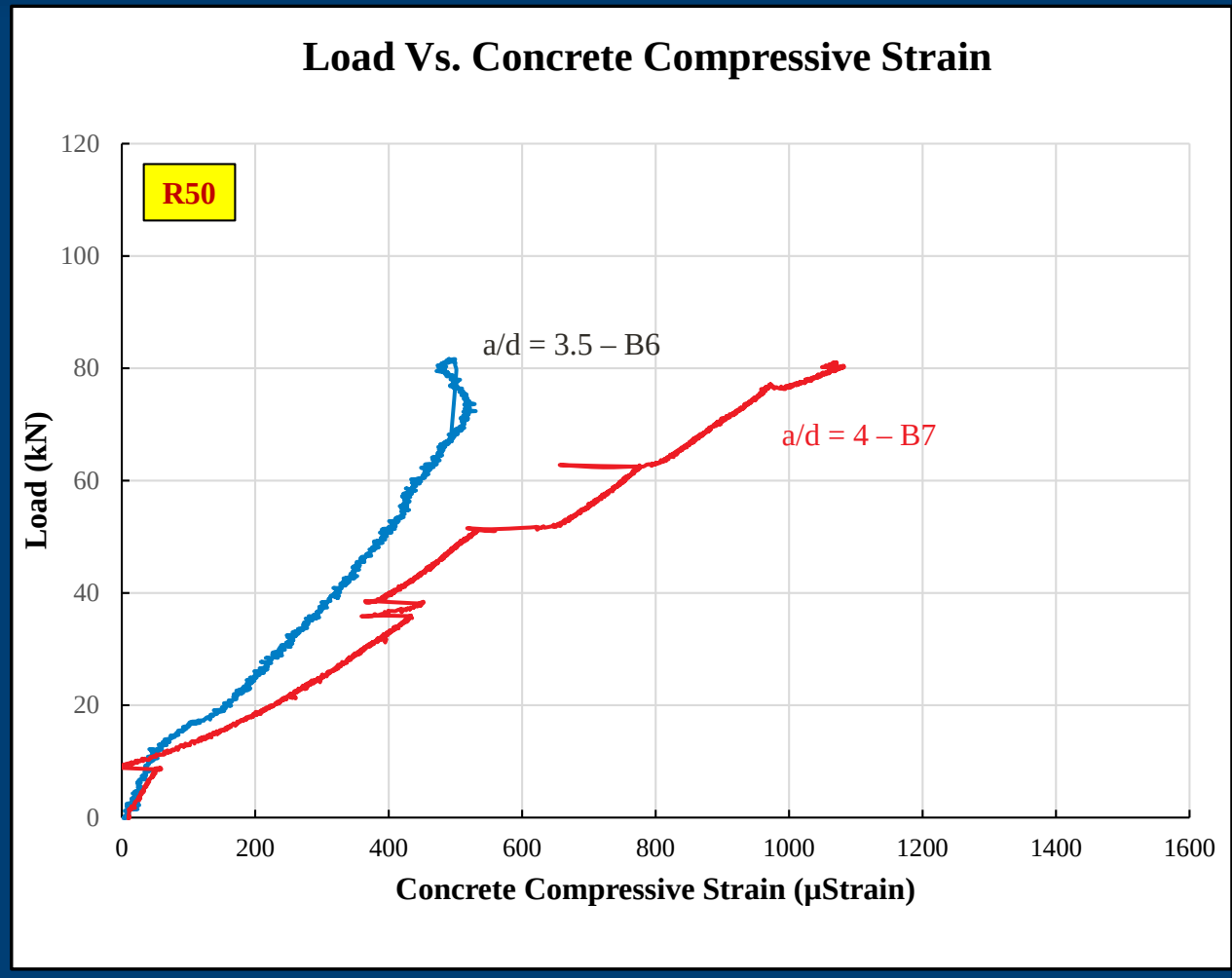
## R100

- For (a/d=3.5) an average increase of 37% was observed in mid-span deflection when compared to (a/d=2.5).
- For (a/d=4) the increase reaches 53%.



# LOAD VS. CONCRETE COMPRESSION STRAINS

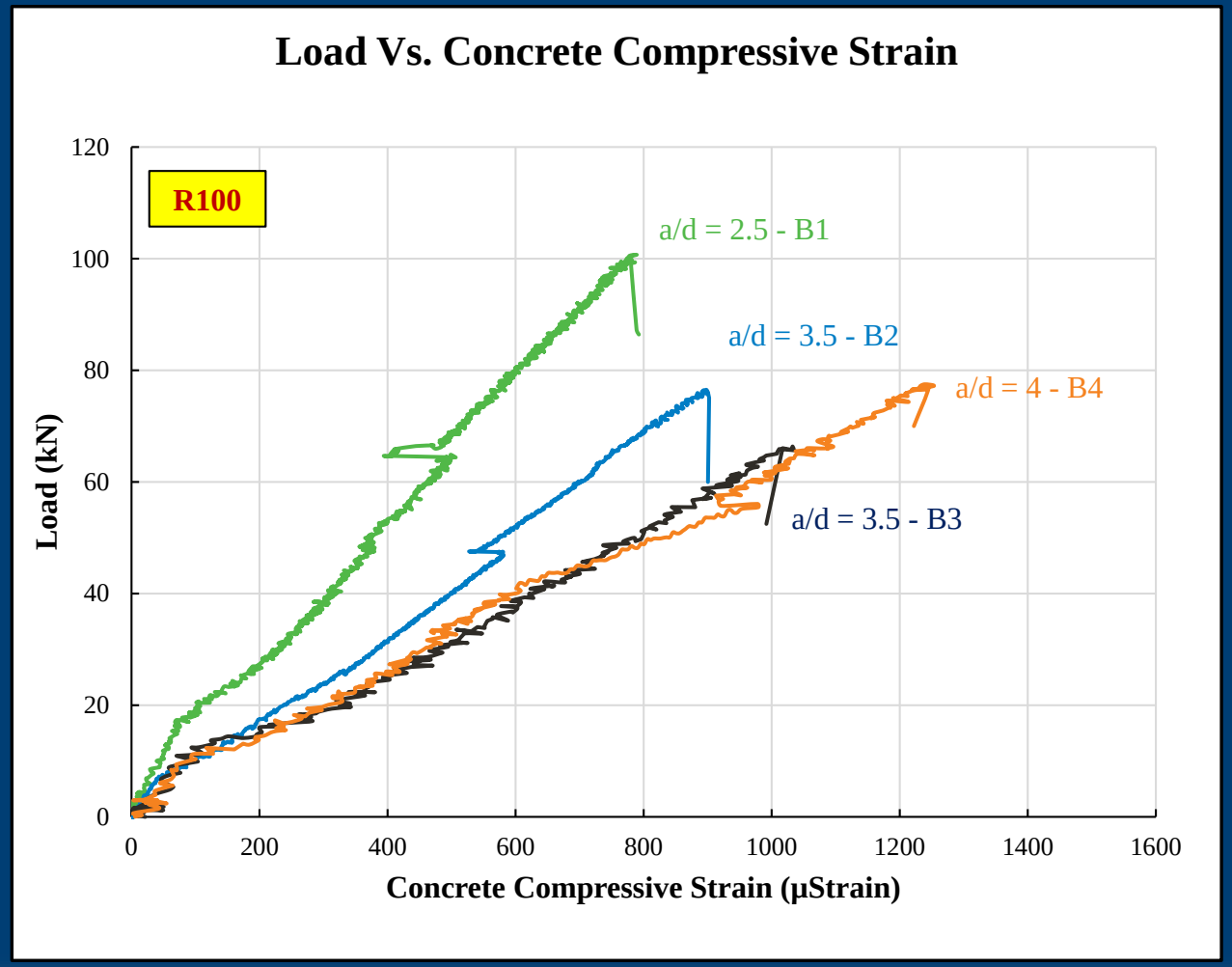


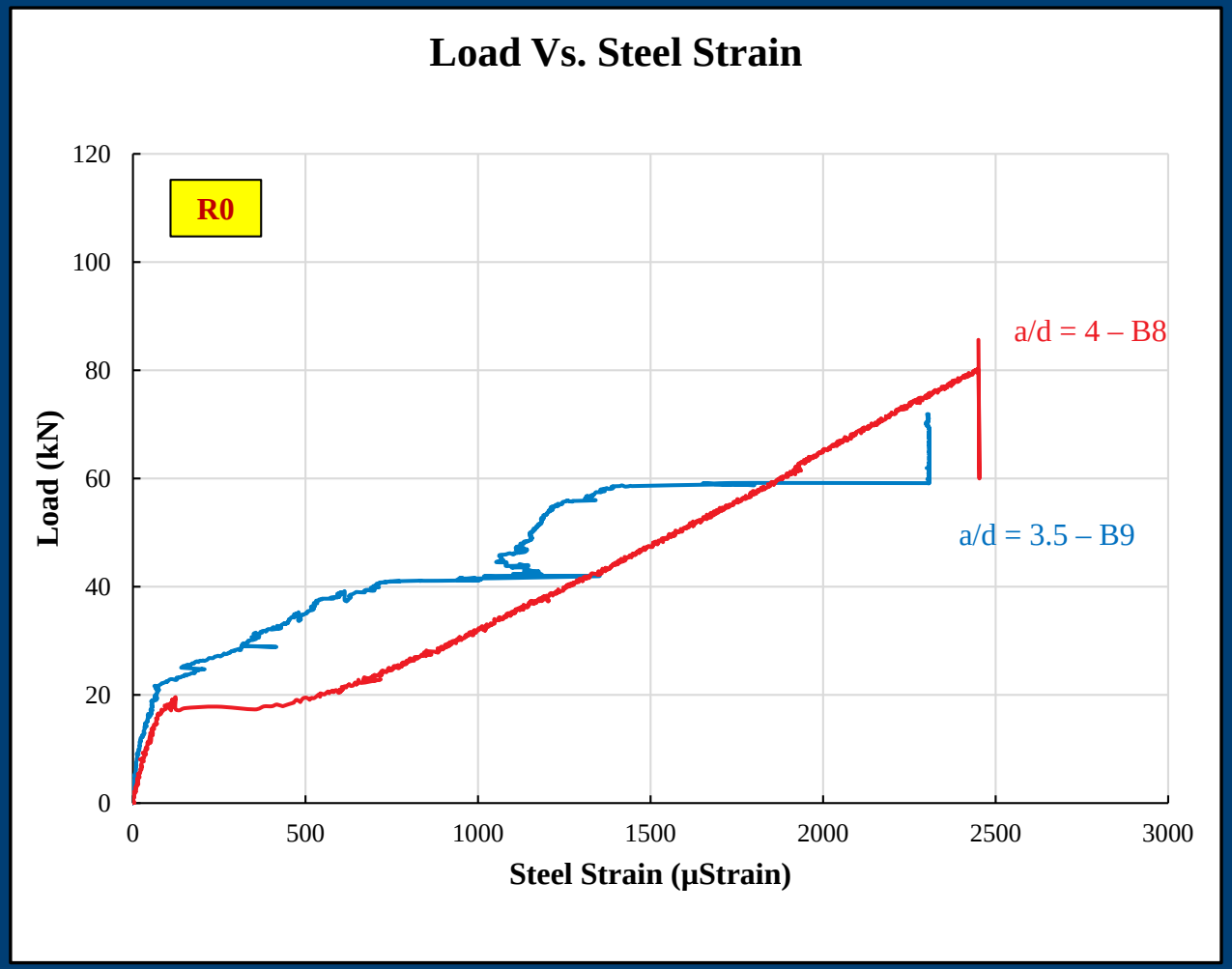
# LOAD VS. CONCRETE COMPRESSION STRAINS

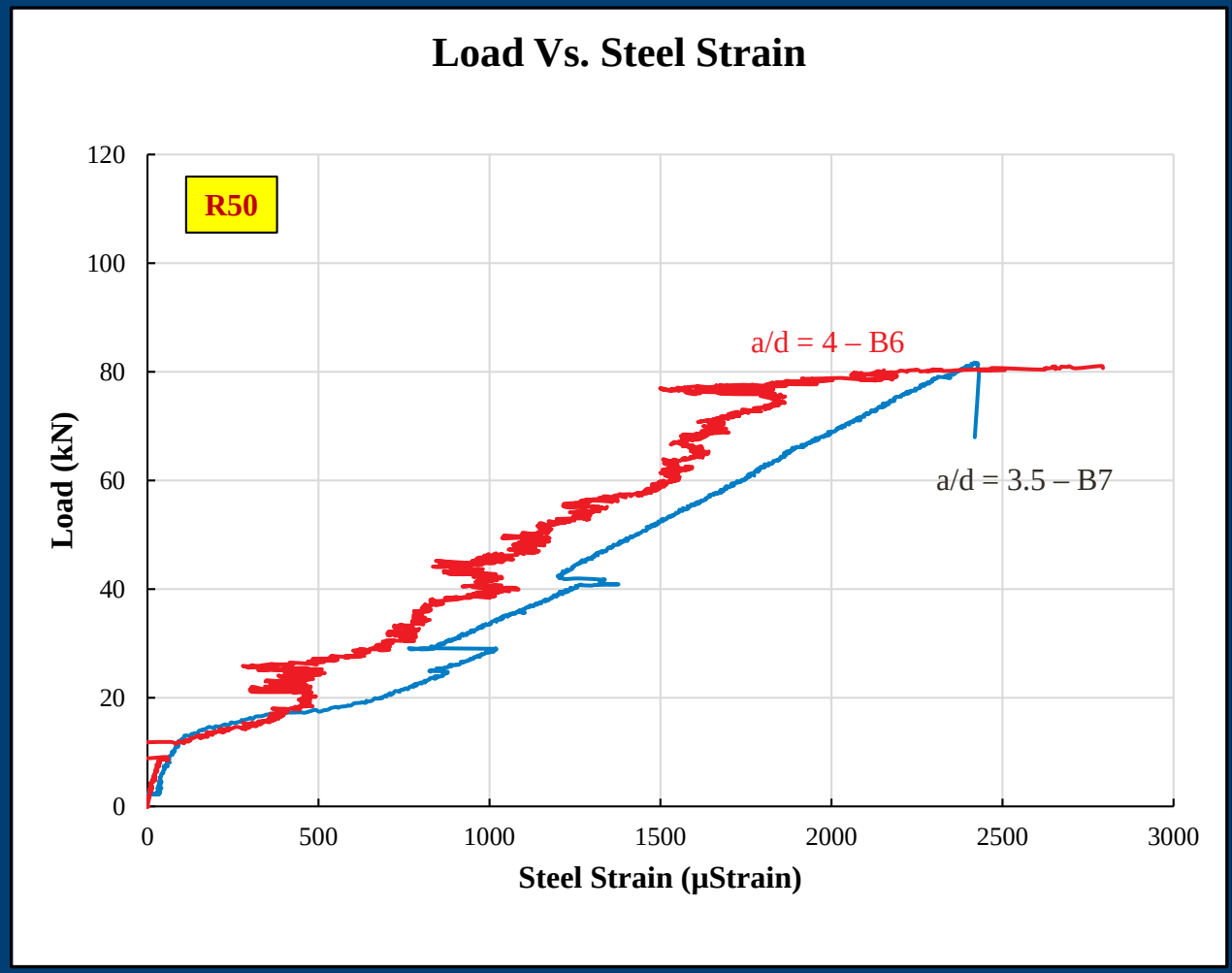
## R100

- For (a/d=3.5) an average increase of 85% was observed in concrete compressive strains when compared to (a/d=2.5).
- For (a/d=4) the increase reaches 123%.



# LOAD VS. STEEL STRAINS

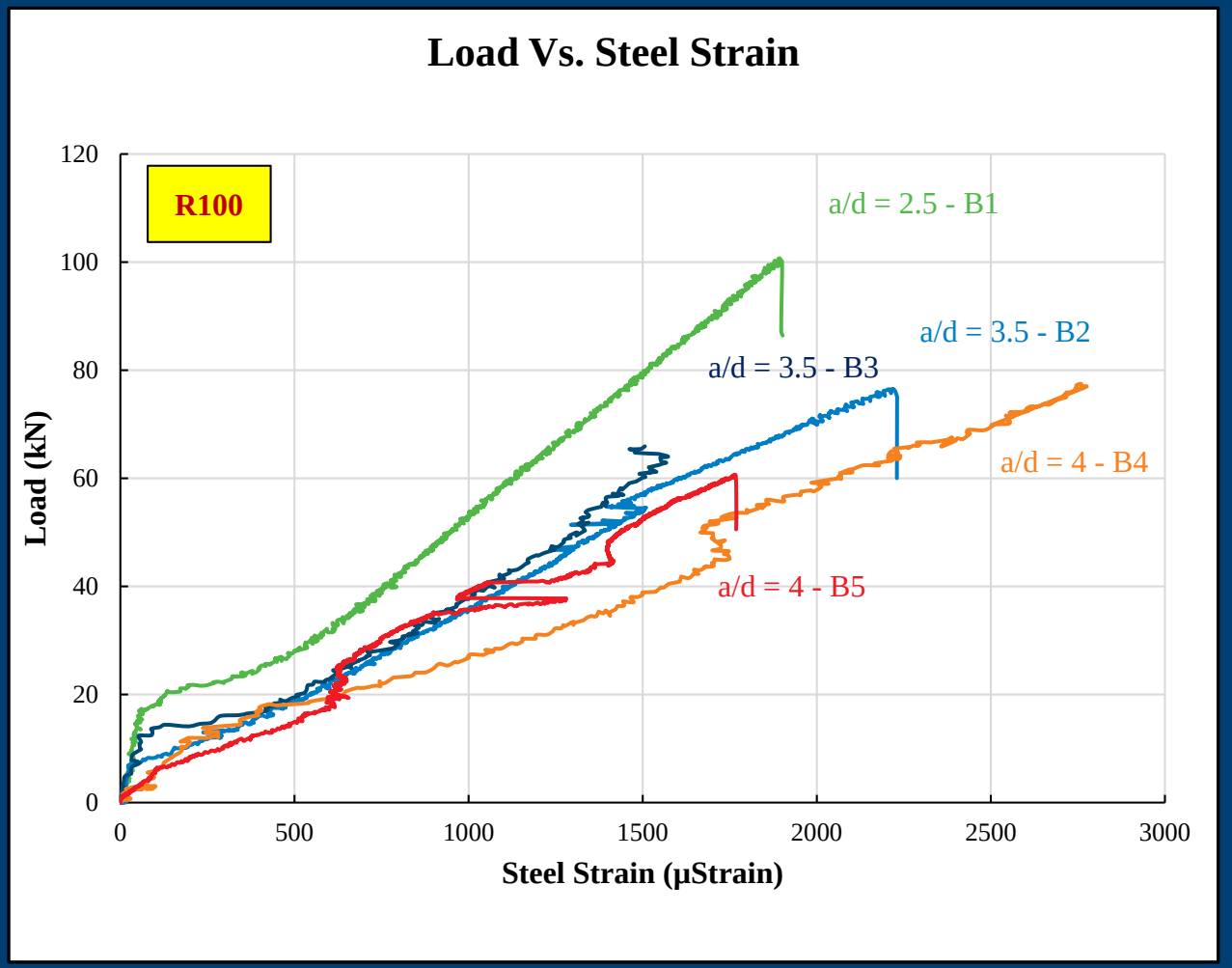


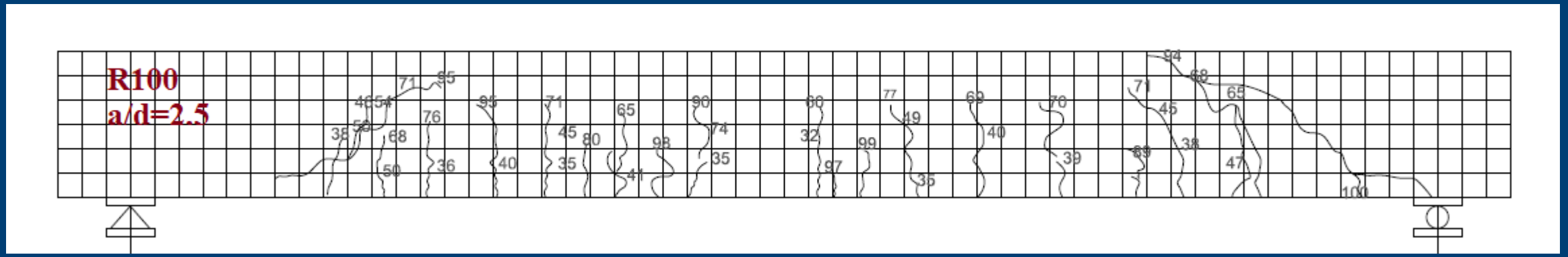
# LOAD VS. STEEL STRAINS

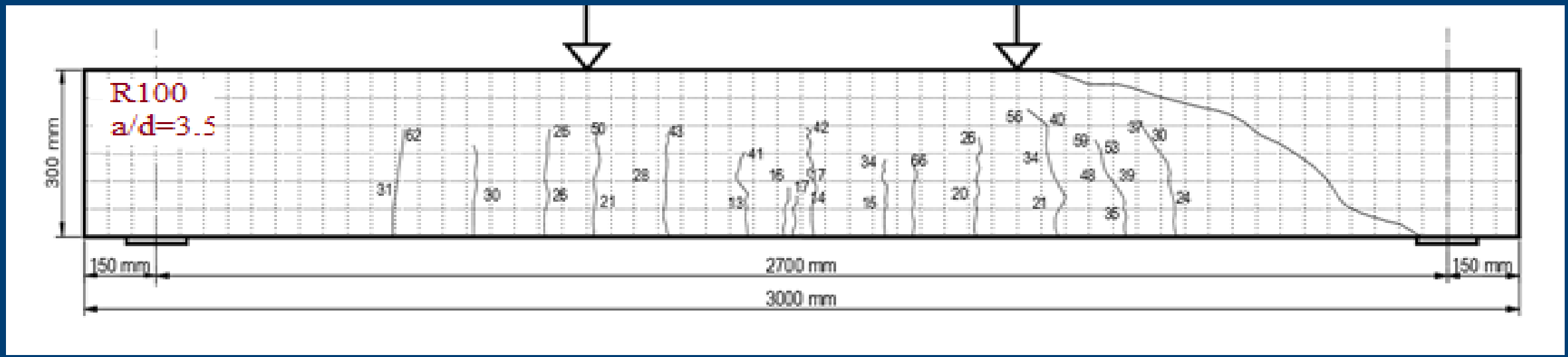
## R100

- For (a/d=3.5) an average increase of 26% was observed in steel strains when compared to (a/d=2.5).
- For (a/d=4) the increase reaches 61%.

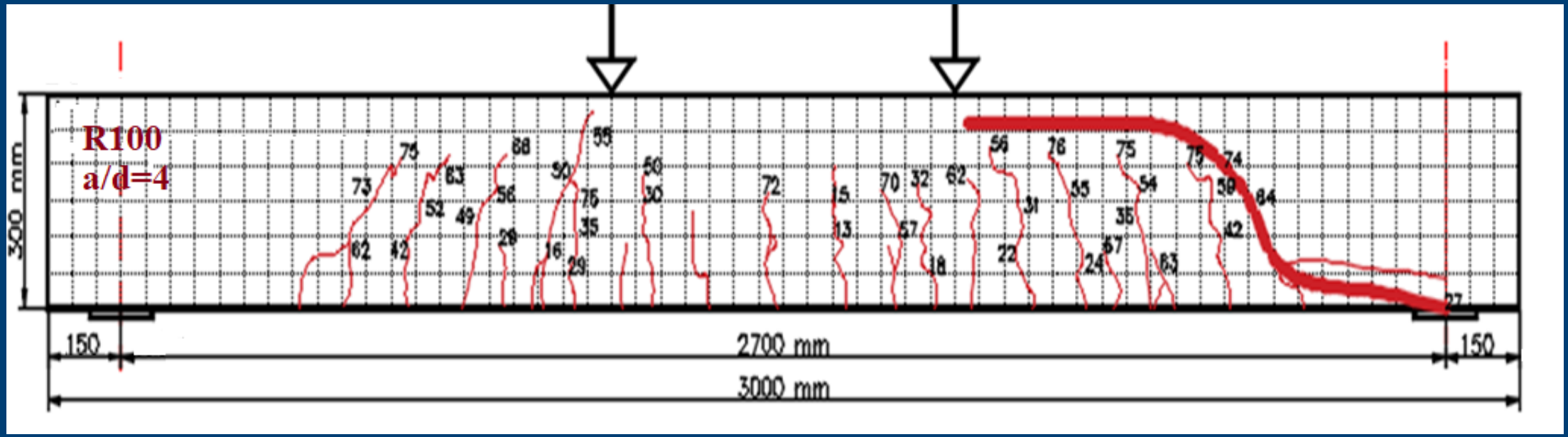


# CRACK PATTERN

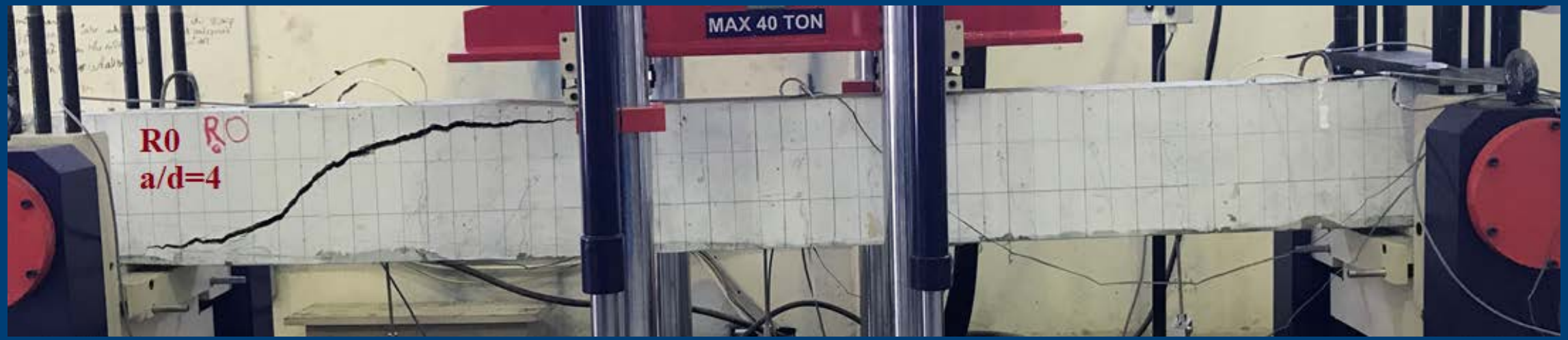


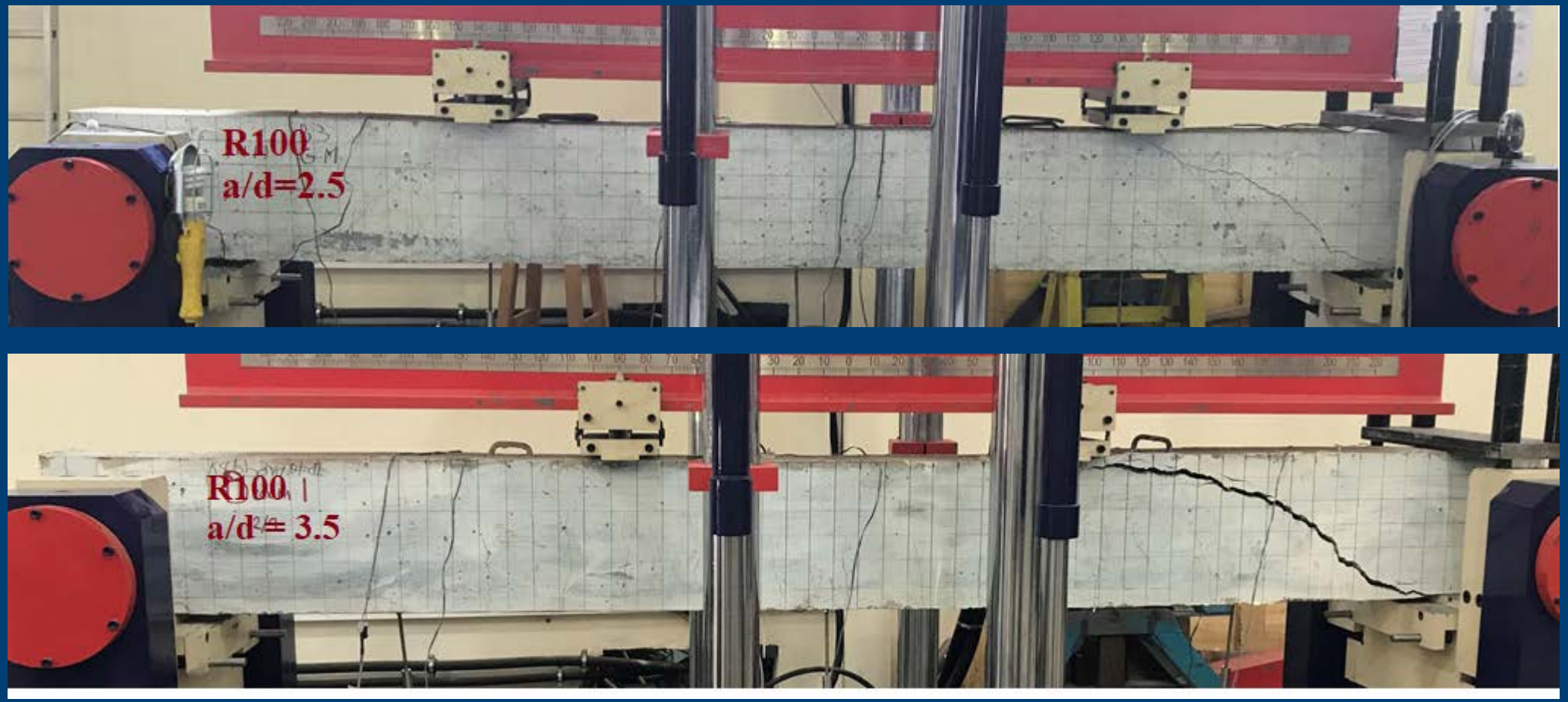
# CRACK PATTERN



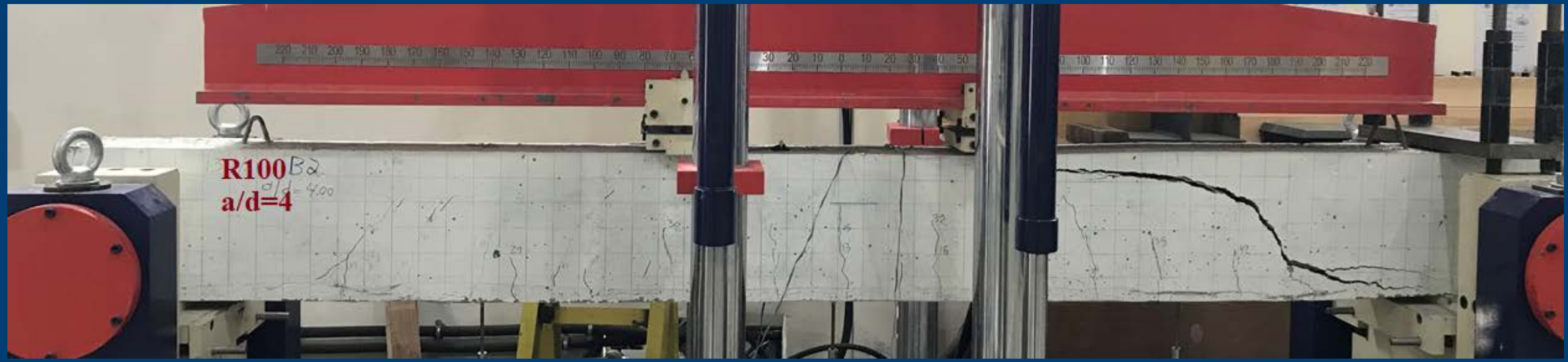
# FAILURE MODE

# FAILURE MODE



# FAILURE MODE



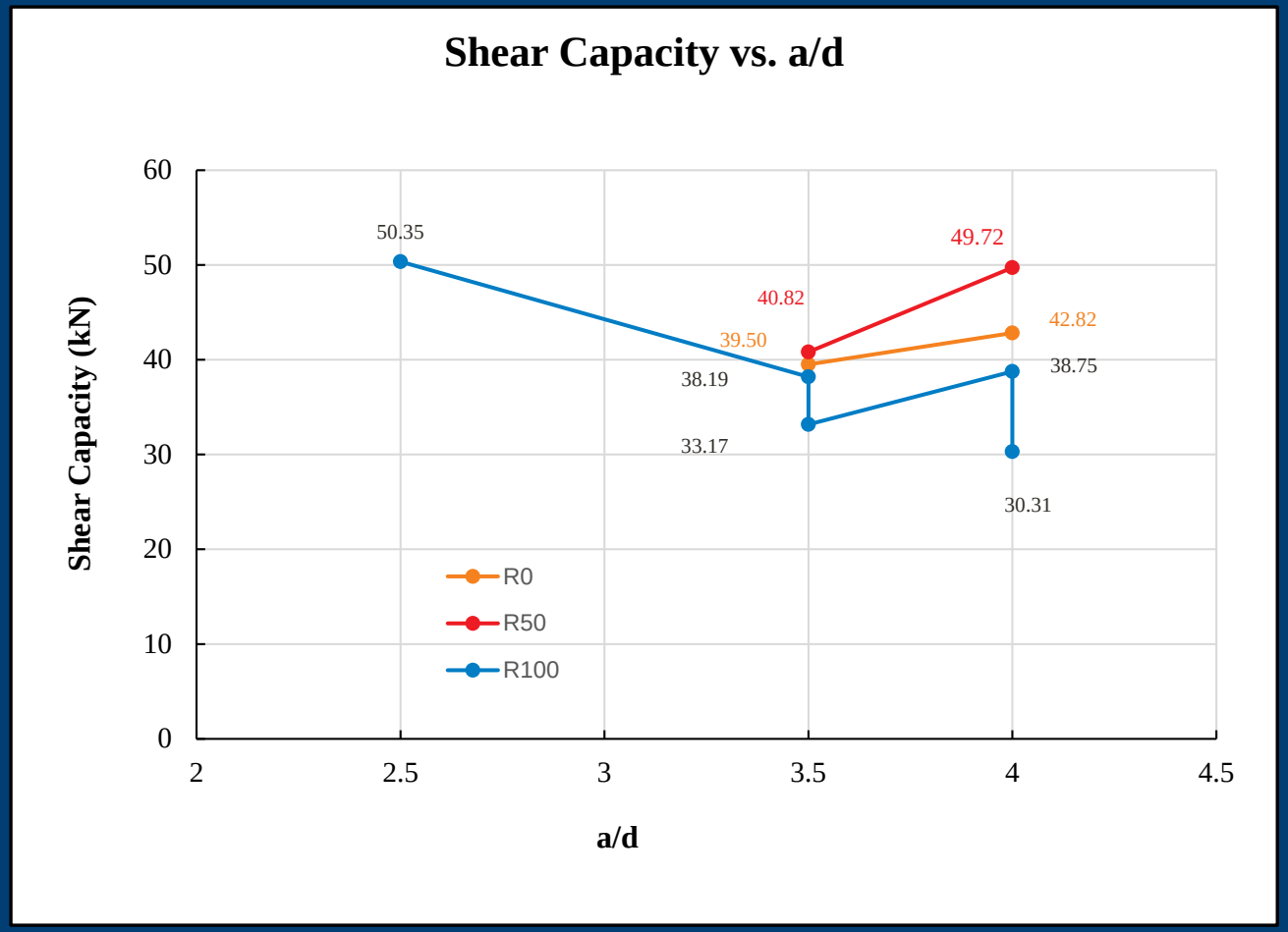
# SHEAR CAPACITY

| Beam | RCA % | a/d | $V_{test}$ kN | $V_{ACI}$ kN | $V_{test}/V_{ACI}$ |
|---|---|---|---|---|---|
| B1 | 100 | 2.5 | 50.35 | 40.52 | 1.24 |
| B2 | 100 | 3.5 | 38.19 | 40.11 | 0.95 |
| B3 | 100 | 3.5 | 33.17 | 37.85 | 0.88 |
| B4 | 100 | 4 | 38.75 | 40.28 | 0.96 |
| B5 | 100 | 4 | 30.31 | 33.88 | 0.89 |

# SHEAR CAPACITY

| Beam | RCA % | a/d | $V_{test}$ kN | $V_{ACI}$ kN | $V_{test}/V_{ACI}$ |
|---|---|---|---|---|---|
| B6 | 50 | 3.5 | 40.82 | 40.92 | 1.00 |
| B7 | 50 | 4 | 49.72 | 43.32 | 1.15 |
| B8 | 0 | 3.5 | 39.50 | 38.56 | 1.02 |
| B9 | 0 | 4 | 42.82 | 41.63 | 1.03 |

# SHEAR CAPACITY vs a/d RATIO



# CONCLUSIONS

- For R0 and R50, deflections were of comparable values.
- For R100 series, deflections increase as (a/d) ratio increases.
- For all replacement ratios, concrete compression strains increase as (a/d) ratio increases.
- Overall, crack patterns and failure modes of RAC beams were similar to those of CC beams.

# CONCLUSIONS

- For R100 series, shear strength decreases as (a/d) increases, while for R0 and R50, the opposite was observed.
- Although ACI provision for shear strength prediction tends to be adequate for CC beams, it overestimates the shear strength for R100 as (a/d) increases.

# Thank you

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