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# ANALITICAL STUDY OF FLEXURAL STRENGTH AND DRIFT CAPACITY OF RC BEAMS UNDER MONOTONIC LOADING

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### *Abstract*

*In recent year, high-strength concrete has becomes increasing popular. However, there are a limited number of tests of high-strength concrete beams. The aim of this paper is to evaluates flexural strength and drift capacity of RC beams specimens using conventional- and high-strength concrete materials. All specimens were tested under four-point monotonic loading. The measured compressive strength of the concrete is in the range of 18 – 126 MPa, longitudinal reinforcement yield strength is in the range 377 – 533 MPa and transverse reinforcement yield strength is in the range 377 – 541 MPa. Test parameters include specimen aspect ratio (a/d), $V_n.a/M_n$ ratio, and maximum strain. Flexural strength of RC beams using conventional- and high- strength concrete calculated by ACI 318-14 and the results are close with experimental test result. Based on limited database results, for concrete compressive strengths greater than 55 MPa, increase of the outmost steel's tensile strain leads to an increase of ultimate drift capacity.*

**Keywords:** ***beam, flexural, drift, high-strength, concrete***

## Introduction

In the practice, concrete strength has been continuously increased since ultimate strength design (USD) method is first introduced in the ACI Code (ACI Committee 318-56). At the time, the equivalent stress block was developed based on majority of concrete cylinder strength between 7 and 35 MPa (Whitney, 1937; Hognestad et al., 1955).
High-strength concrete (HSC) has becomes increasing popular in recent years because of increasing demands of high-rise buildings in urbans areas. With an increases in concrete strength, the member size can be reduced to carry the design loads. Reduced member size increase the amount of rentable space and is especially beneficial when there are architectural restrictions on vertical member size (Smith and Rad, 1989).
When subjected to axial load, load-carrying of the concrete cylinder decreases more rapidly as the concrete strength increases, Fig. 1.

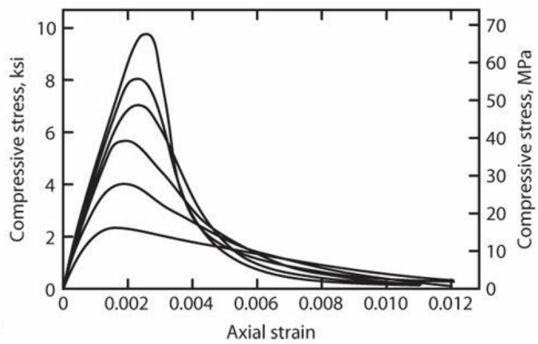


**Figure 1.** Stress-strain relationship of normal weight concrete under uniaxial compressive loading (Wischers, 1979).

Rashid and Mansur (2005) reported test results of sixteen reinforced concrete beams using concrete with compressive strength varying between 42 and 126 MPa. Based on test results of the four specimens that used the same reinforcement layout but different concrete strength as shown in Fig. 2, it appears that specimen deflection ductility increases as the concrete strength increases but only up to around 70 MPa.

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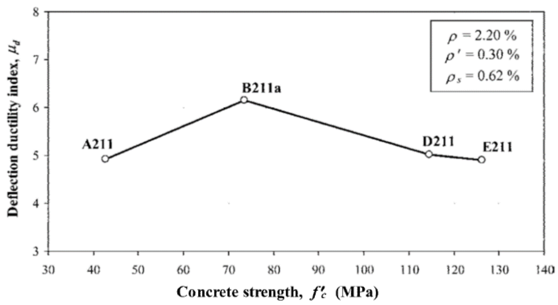



**Figure 2.** Beam ductility as influenced by concrete strength (Rashid and Mansur, 2005)

The aim of this paper is to evaluates flexural strength and drift capacity of RC beams using conventional- and high- strength concrete. The flexural strength of RC beams calculated using ACI stress block models.

## Research methods

A total of 50 reinforced concrete beams specimens are collected, 35 of which are using conventional-strength concrete while the remaining 15 using high-strength concrete. All specimens were tested under a four-point loading experimental setup, as shown in Fig. 3. The two concentrated loads were applied symmetrically from the midspan.

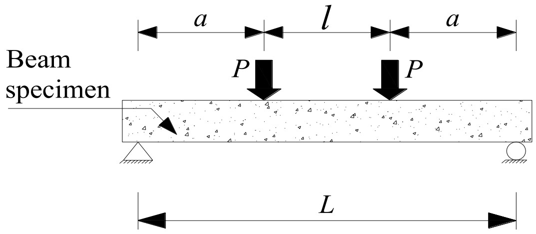
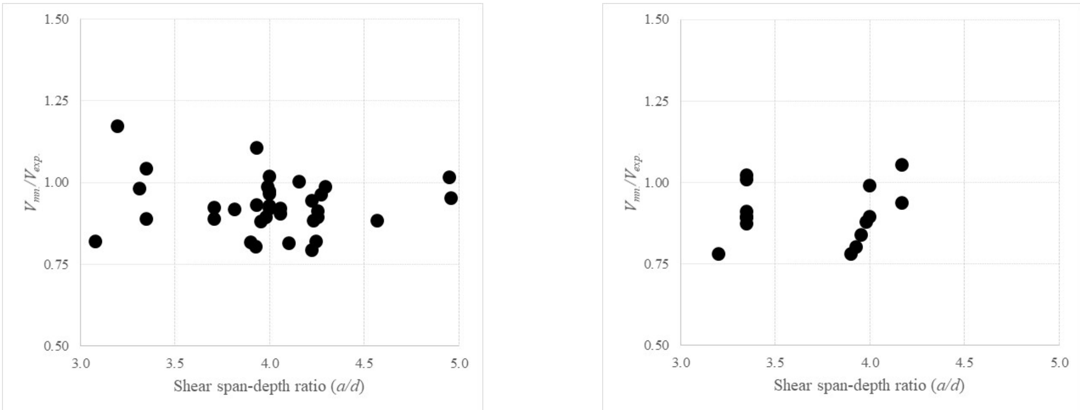



**Figure 3.** Typical experimental setup

The range of material properties for the collected beams specimens are listed as follows: shear span-depth ratio ($a/d$): 3.08 – 4.96; concrete cylinder strength ($f_c$'): 18 – 126 MPa; longitudinal reinforcement yield strength ($f_y$): 377 – 533 MPa; transverse reinforcement yield strength ($f_{yt}$): 377 – 541 MPa; minimum diameter of transverse reinforcement: D10; and $V_n.a/M_n \geq 1$, where $V_n$ is specimen nominal shear strength using tested material properties, $P$ is load, $a$ is shear span and $d$ is effective depth.

## Research Results and Discussion

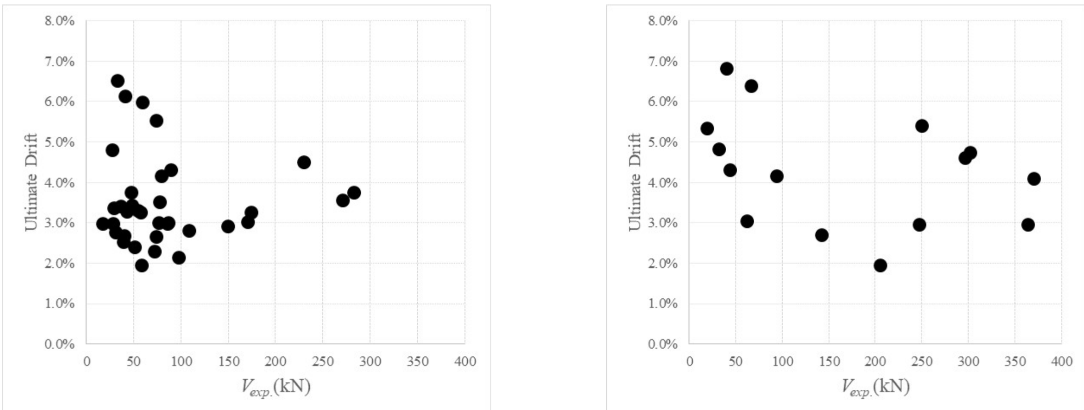
As presented in Fig. 4(a) and Fig. 4(b), $V_{mn}/V_{exp}$ of each specimen fits closely to the experimental data with a mean value of the ratio 0.93 and 0.90 for specimens with conventional-strength concrete and high-strength concrete, respectively. Conventional-strength concrete using $f_c$*'* from 18 MPa to 55 MPa. In other hand, high-strength concrete using $f_c$*'* from 64 MPa to 126 MPa.




(a) Conventional-strength concrete (b) High-strength concrete

**Figure 4.** Shear capacity ration $V_{mn}/V_{exp}$ due to flexural capacity

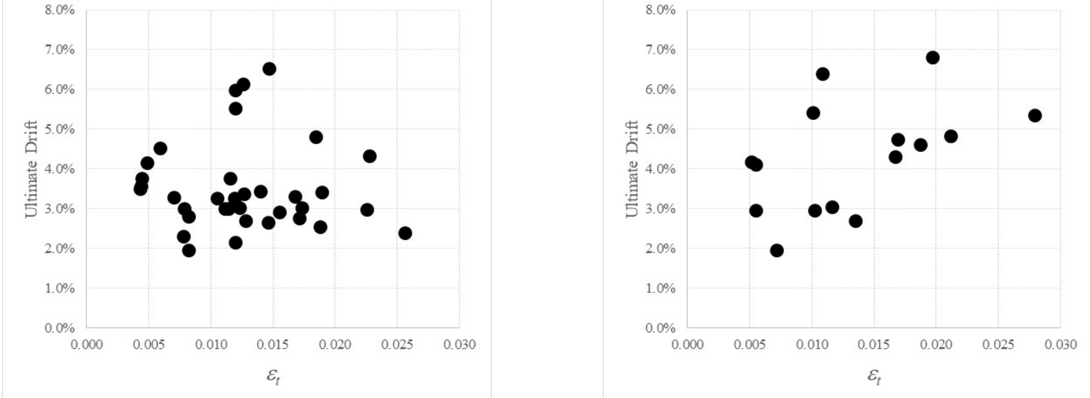
The $V_{exp}$ – ultimate drift relationship of all specimens in the database are presented in Fig. 5(a) and Fig. 5(b) for specimens with conventional-strength concrete and high-strength concrete, respectively. The ultimate drift is defined as the midspan displacement corresponding to a 20% load drop from the peak divided by half of the simple span. The ultimate drift of all specimens between 2.0% to 7.0%. Based on Pic. 5(a) and Pic. 5(b), $V_{exp}$ do not show significant correlations with the ultimate drift capacity.




(a) Conventional-strength concrete (b) High-strength concrete

**Figure 5.** Ultimate drift versus $V_{exp}$

The $\varepsilon_t$ – ultimate drift relationship of all specimens in the database are presented in Pic. 6(a) and Pic.6(b) for specimens with conventional-strength concrete and high-strength concrete, respectively. $\varepsilon_t$ represents the outmost steel tensile strain. Pic. 6(b) shows that an increase of the outmost steel's tensile strain leads to an increase of ultimate drift capacity.




(a) Conventional-strength concrete (b) High-strength concrete

**Figure 6.** Ultimate drift versus $\varepsilon_t$

## Conclusions and recommendations

Based on the limited database for conventional- and high- strength concrete in this current study, following conclusions can be drawn:

1. Flexural strength of beams using high-strength concrete can be estimated using ACI 318-14 code.
2. For concrete compressive strengths greater than 55 MPa, increase of the outmost steel's tensile strain leads to an increase of ultimate drift capacity.

Readers should be reminded that findings of this paper are based on limited database and future studies are needed to verify the findings.

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