Mechanical Properties and Evaluation of Concrete Beams Made of a Large Amount of Fine Fly Ash

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Summary

Nine reinforced concrete beams were fabricated and tested under monotonic shear and bending to investigate effects of the fine fly ash content on ultimate shear strength and deformation capacity of concrete beams. Taking the fine fly ash content, the shear span ratio, and the section size of beams as primary experimental variables, all test beams were prismatic beams and made of concrete with a water-to-cement ratio as low as 65%. Test results have indicated that increasing the fly ash content can enhance both ultimate shear strength and deformation capacity. The larger the quantity of fine fly ash, the higher the shear strength and the rotation angle at the peak shear. The use of 455 kg/m^3 fly ash per unit volume in a concrete beam, which had no transverse hoops and had shear span ratio of 1.0, could enhance the ultimate rotation angle of the beam up to 0.02 radian.
Keywords: fine fly ash; concrete beam; ultimate shear strength; flexural strength; shear span ratio; ultimate rotation angle.

1. Introduction

Fly ash, an industrial waste mainly produced from thermal power plants, has found its wide application in diverse fields such as cement, fishery, agriculture, and construction since 1950s. In Japan, utilization of fly ash in cement industry accounts for up to 90% of its total application. However, the economic recession having lasted for the last two decades in Japan has significantly reduced the demand of construction and hence cement. From the viewpoints of effective use of industrial wastes and mitigation of environmental burden by concrete industry, development of a new and effective application of the fly ash is urgent and desirable.
Matsufuji *et al*. [1] proposed a new application method for the fly ash in concrete. In this method, the fly ash is used in partial place of fine aggregate, while the cement content will be kept constant. They have experimentally verified that the compressive strength of concrete increases along with the mixing quantity of fly ash up to 300 *l* /m^3 with a constant water-to-cement ratio of 65%.

Objectives of this paper is to present experimental information on the mechanical properties of concrete beams made of a large quantity of coal fly ash with emphasis placed on the ultimate shear strength and rotation angle of fly ash concrete beams.

2. Outline of experiment

The experiment in this study involved nine prismatic rectangular concrete beams. The nine specimens were divided into two groups according to the dimensions of cross section. The first group had five rectangular beams with cross section of 250mm in width and 400mm in depth, while the section dimension

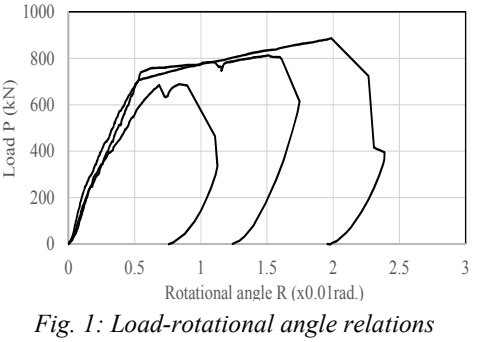

Fig. 1: Load-rotational angle relations

of the beams in the second group was 150mm x 250mm. Among the nine specimens, the experimental variables were the shear span ratio (1.0, 1.5, and 2.0), the fly ash quantity (0kg/m^3, 244kg/m^3, and 455kg/m^3), and the type of longitudinal rebars. All test beams were under monotonic vertical loading with simple supports at their ends.

3. Experimental results and discussions

Fig. 1 shows examples of the measured vertical load (P) versus rotational angle (R) relationships of the short columns, which had shear span ratio of 1.0 and no transverse hoops. It can be seen from Fig. 1 that the short beams exhibited increasing load-carrying capacity and deformability along with the increment of fly ash quantity. Though there was no transverse hoops, mixing fly ash of over 455kg/m^3 in per unit volume could assure short beams reinforced by normal-strength rebars develop their flexural strength and enlarge their deformability in terms of rotational angle up to about 0.02rad. For the concrete beams with shear span ratio larger than 1.5, replacing the fine aggregate with fly ash of 455kg/m^3 in per unit volume could make the beams reinforced by normal-strength rebars behave very stably up to R larger than 0.05rad.

4. Evaluation of flexural and shear strengths of the fly ash concrete beams

The design equations for general concrete beams in Japanese design code were applied to evaluate ultimate shear and flexural strengths of fly ash concrete beams. Comparison between the measured results and the theoretical predictions has indicated that the current equation for calculating flexural strength underestimated the experimental results due to the ignorance of effects by both moment gradient and strain hardening of longitudinal rebars. As to the shear strength, the design equation tended to underestimate the test results of the specimens with smaller section size. This may be attributed to that the factor accounting for the size effect isn't absolutely accurate and that the size effect isn't as significant as the structural community has anticipated.

5. Conclusions

1) The ultimate load-carrying capacity and rotational angle at peaks of concrete beams tended to increase along with the quantity of fly ash which was used to partially replace fine aggregate. Mixing fly ash by 455 kg/m^3 per unit volume can enhance the ultimate rotation angle up to 0.02rad for the concrete short beam without any transverse reinforcement.

2) For the concrete beams reinforced by normal-strength rebars and containing a large quantity of fly ash, the design equation for general concrete beams could give a conservative but reasonable prediction to the flexural strengths of the fly ash concrete beams.

3) The shear strength of fly ash concrete beams with smaller section size was underestimated with a large margin by the design equation recommended in current design code for general concrete beams. To accurately predict the shear strength of the fly ash concrete beams, the size effect of fly ash concrete beams on the shear strength needs to be further investigated.

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