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Dhuha Kareem Hassan ✉; Sa'ad Fahad Resan; Hayder Al-Khazraji

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Moment Redistribution Assessment of Continuous Reinforced Concrete Beams of Hybrid Concrete Strength: Experimental Study

Dhuha Kareem Hassan[1, a)], Sa'ad Fahad Resan[1, b)] and Hayder Al-Khazraji[1, c)]

[1] *Civil Engineering Department, Engineering College, University of Misan, Amarah, Iraq.*

[a)] *Corresponding author: duhakareem12123@uomisan.edu.iq*
[b)] *sadresan@uomisan.edu.iq*
[c)] *hayder_alkhazraji@uomisan.edu.iq*

Abstract. The current study intends to use moment redistribution concept besides the smart utilization of concrete strength to develop continuous reinforced concrete beams using hybrid concrete of normal and high strength grades in addition to investigates the effectiveness of introduced hybrid modes upon moment redistribution and related issues such as strength capacity, load deflection response, flexural stiffness, flexural ductility, and the mechanism of failure. The experimental program consists of manufacturing and testing six specimens of 3000×200 120 mm divided into two groups, the first one related to specimens of homogeneous concrete strength of, 60 MPa which denoted as high strength and the second group related to specimens of hybrid concrete strength the layer of 60 MPa and the lower layer of 20MP. Although of the significant reduction in section strength of in lower layer in hybrid mode for one third (from 60 to 20 MPa), the results depict that, the moment capacity, flexural stiffness and flexural ductility tends to get improving with the mid span enhancement rating increasing which is compatible with attained moment redistribution.

Keywords: Moment Redistribution, Reinforced Beams, Continuous Beams, High Strength Concrete and Hybrid Strength Concrete.

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INTRODUCTION

Smart section area distribution and appropriate strength selection are the key parts in the design philosophy for cost-effective structural members. The main elements for the success of any project are durability, cost, and construction time, as well as understanding the factors of complexity. The use of these features in each part of the project reduces the cost of construction while also reducing the time it takes to complete. Additionally, the concrete members are the most essential components of the construction project, and enhancing their properties, increasing their strength, and using additives certain, and simple construction methods contribute effectively to the project's success [1].

Improving the properties of concrete involves using additives to increase its strength [2], as well as implementing them in specific forms that are appropriate to the facility, which contributes to increased durability in general, while using hybrid concrete significantly reduces construction costs [3].

Throughout recent years, the redistribution moment concept in continuous concrete beam had been considered by many researchers. Moment redistribution is a particular behavior observed in statically indeterminate reinforced concrete constructions as a result of structural redundancy and nonlinear reinforced concrete characteristics, merged with many techniques to enhance the structural behavior according to the strength compressive strength or the rate of enhancement according to ACI code or B.S [4; 5; 6; 7; 8 and 9]. In other side, R.C. beams of hybrid compressive strength were considered as a smart technique to reduce the overall design cost [10, 11; 12; 13; 14; and 15].

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EXPERIENTAL PROGRAM

Mix Design

Two concrete mixes were used to investigate the influence of concrete strength on the behavior of continuous hybrid strength reinforced concrete beams of rectangular section. One of them was normal concrete (20) MPa and another one was high strength (60) MPa. The mix proportions of the ingredients of the normal mix [1 cement: 2 sand: 4 gravel], and the w/c ratio were 70%, to get cube compressive strength of about 20 MPa at age of 28 days. For the second mix, the proportions of the ingredients of the high strength mix [1 cement: 1 sand: 2 gravel], and the w/c ratio were 34%, and 0.6% superplasticizer by weight of cement to get a cube compressive strength of about 60 N/mm^2 at age of 28 days. The contents considered in the preparing of the two types of concrete are listed in TABLE 1.

TABLE 1. Weights of materials included in concrete mixtures

ID Matrix	Symbol of Concrete	Cement (kg/m^3)	Sand (kg/m^3)	Gravel (kg/m^3)	W/C	Super Plasticizer (kg/m^3)	F_{cu} (MPa) in 28 Days
1	Normal Strength Concrete	308.9	617.8	1235.6	0.7	-	20
2	High Strength Concrete	540.85	540.85	1081.7	0.34	3.25	60

An experimental work is presented which included mix design, preparation the required materials and the specimens manufacturing as well as the experimental test set-up. Two groups as a reference of specimens are considered the first without any strength reduction and it is of 60 MPa and denoted as a high strength while the second group related to developed specimens of hybrid strength (consists of two layers, upper layer of 60 MPa and lower layer of 20 MPa). The specimens were casting and testing in engineering Misan university, the ultimate load of testing machine was 600 KN. Throughout the study, the structural behavior and the moment redistribution of suggested mode is considered in addition to comparative analysis between them. A total of six reinforced continuous concrete beams were prepared and tested. All the six beams were similar in their dimensions but the difference in steel reinforcement details, the overall length of the specimens was 3000 mm and the cross-section were (120x200) mm width and depth respectively. the Kong and Evans (2017) concept is adopted for determination redistribution of the moments, the main variables were concrete compressive strength reduction in hybrid mode, moment redistribution ratios which are compatible with enhancement rates (R) verse reduction rates (00%, 15% and 30%) were adopted to BS 8110 permits up to 30% moment redistribution, which is produced a significant variation in moment redistribution rates in midspan region (q_m) and middle support region (q_s) and this variation and so, the provided steel reinforcement to be compatible with those rates, the controlled of enhancement rates of the tested specimens through the design of them, **FIGURE .1** illustrates the adopted enhancement rates and related moment redistribution while the geometrical details of developed specimens are shown in **TABLE.2**. **FIGURE .2** clearly shows geometrical details of all specimens which are designed according to ACI Committee 318 [16] while **FIGURES 3, 4**, and **5** depict the manufacturing procedure, used material test setting which are tested according to standard specifications [17, 18 and 19], and the specimen test arrangement, respectively.

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