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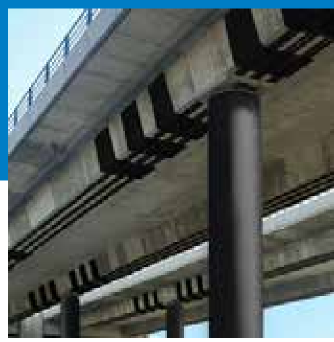

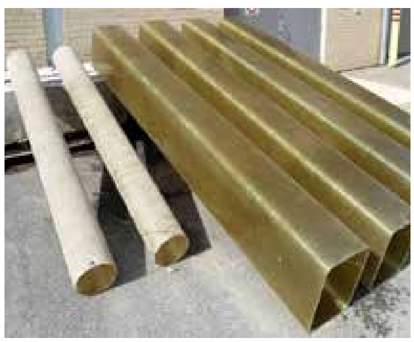

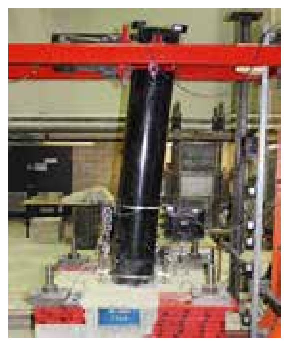

Development and Applications of FRP Reinforcements (DA-FRPR'21)

SP-356

Editor:
Radhouane Masmoudi

American Concrete Institute
Always advancing

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Sponsored by
ACI Committee 440

ACI Virtual Concrete Convention
October 17-21, 2021

Editor:
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First printing, October 2022

Discussion is welcomed for all materials published in this issue and will appear ten months from this journal's date if the discussion is received within four months of the paper's print publication. Discussion of material received after specified dates will be considered individually for publication or private response. ACI Standards published in ACI Journals for public comment have discussion due dates printed with the Standard.

The papers in this volume have been reviewed under Institute publication procedures by individuals expert in the subject areas of the papers.

Printed in the United States of America

Editorial production: Susan Esper

ISBN-13: 978-1-64195-195-1

Preface

Fiber-reinforced polymer (FRP) reinforcements for concrete structures and civil engineering applications have become one of the innovative and fast-growing technologies to stop the rapid degradation of conventional steel-reinforced concrete infrastructure. FRP reinforcements for construction can be divided into three main types: 1. External sheets or plates to rehabilitate and repair existing concrete and masonry structures, and in some cases steel and wood structures; 2. Internal FRP bars or tendons for new and existing reinforced concrete structures, and 3. FRP stay-in-place forms to be filled with unreinforced or reinforced concrete. A considerable and valuable development and application's work has been accomplished during the last three decades, leading to the development of numerous design guidelines and codes around the world, making the FRP-reinforcement technology one of the fast-growing markets in the construction industry. During the ACI Concrete Convention, Fall 2021, four full sessions were sponsored and organized by ACI Committee 440. Session S1 was focused on the bond and durability of internal FRP bars; Session S2 on codes, design examples, and applications of FRP internal reinforcements; Session S3 on external FRP reinforcements; and Session S4 on new systems and applications of FRP reinforcements, such as CFFT post-tensioned beams, GFRP-reinforced concrete sandwich panels, FRP-reinforced masonry walls, CFFT under impact lateral loading, near-surface mounted FRP-bars, and GFRP-reinforced-UHPC bridge deck joints.

I would like to address my sincere thanks to the reviewers for their valuable dedication to review the submitted papers. Thanks to the authors for their patience during the review process. A special thanks to ACI Committee 440 Chairs, William J. Gold and Maria Lopez, for their support and collaboration in organizing these four full sessions! Thanks to Barbara Coleman, ACI SP & Session Coordinator, for her collaboration in organizing the full sessions and during the editing of the SP publication.

This ACI Special Publication is dedicated to my love Dima and my three children Nour, Alae, and Layana!

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TABLE OF CONTENTS

SP-356—1

Bond Study of Corrosion-Free Reinforcement Embedded in Eco-Friendly Concrete

Ali F. Al-Khafaji, John J. Myers, and Hayder H. Alghazali

Synopsis: This paper presents an investigation of the bond performance of corrosion-free sand-coated glass fiber reinforced polymer bars (GFRP) implanted in two types of fly ash-based eco-friendly concrete. Steel reinforcement is prone to corrosion and is expensive to fix, therefore finding an effective alternative has become a must. One of these alternatives is GFRP bar. On the other hand, conventional concrete (CC) is not issueless, as it significantly affects the environment through its high-intensity CO_2 emissions. Thus, other alternatives have been looked into to mitigate the CO_2 problems. One of these alternatives is partially substituting Portland cement with another CO_2 emission-free material such as fly ash. In this study, two levels (50% and 70%) of high-volume fly ash concrete (HVFAC) were used to investigate their bond performance with GFRP bars. Cylindrical specimens were tested under the effect of pullout load. Furthermore, the bars were investigated chemically and microstructurally to see if the fly ash had some influence of the GFRP bar. For concrete, performance rank analysis was carried out to identify the best concrete mix in term of slump, unit weight, cost, and bond strength. In addition, to verify the experimental work, two-dimensional finite element models were built using translator elements to present the bond action between the concrete and its reinforcement. The results of investigation showed that the bond strength of GFRP bars were less than that of mild steel owing to GFRP bar deformation. In addition, CC resulted a higher bond strength than HVFAC. The bar analyses did not yield any obvious signs of microstructural deteriorations or chemical attack.

Keywords: Bond Assessment, Pullout, Fly Ash, GFRP bar, Finite Element, SEM, EDS, FiC, Performance Rank Analysis

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INTRODUCTION

Manufacturing of conventional Portland cement is linked to unfavorable consequences on the environment, as it uses substantial quantities of resources and releases significant levels of carbon dioxide (CO_2) emissions to the atmosphere [1]. The most widely consumed material in the field of construction is cement-based concrete [also called conventional concrete (CC)] [2]. Portland cement (PC) has been largely implemented to produce concrete [3]. The cement binding agent is mostly made from clinker which is a product that consumes significant amounts of raw materials and energy in addition to releasing substantial amounts of CO_2 [4]. Thus, the major consumption of raw materials and the significant CO_2 emissions of PC stimulated the civil engineering industry to study and implement alternative supplements to PC such as fly ash, slag, and silica fume that used to be considered as waste products [1]. Fly ash is a by-product resulted from coal-burning thermal power stations [5] and is defined per ASTM C618-08 [6] as "the finely divided residue that results from the combustion of ground or powdered coal and that is transported by flue gases." Fly ash enhances workability, lessen hydration heat and thermal cracking in concrete at early ages and improves durability and mechanical properties of concrete at later ages (Myers and Carrasquillo 2000; Hemalatha and Ramaswamy 2017). Based on the environmental protection agency [8], fly ash implementation in concrete decreases the CO_2 emissions equivalent to emissions from 2.5 million vehicles on road every year. Therefore, substantial reduction in CO_2 emissions can be obtained by increasing the fly ash utilization in concrete. There are mainly two types of fly ash; class F, and C. Class F and C can are obtained from burning anthracite and lignite coals respectively [7]. The main chemical compounds of these two types are Silica (SiO_2), Alumina (Al_2O_3), and Iron Oxide (Fe_2O_3), but what differentiate one from the other is the percentages of those chemical compounds. If they were over 70%, fly ash is considered class F and if they were between 50%-70%, it is considered class C [6]. High volume fly ash (HVFA) concrete per ACI 232.2R can be defined as the concrete with fly ash dosage of 50% or more [9]. An ample studies have been performed on both fresh and hardened properties of HVFA concrete, but very few studies have been carried out to investigate its effect on certain structural behavior such as bond and shear strength (Looney et al. 2013a,b; Alghazali and Myers 2017; Arezoumandi et al. 2013a,b). Gopalakrishnan et al. [11] investigated the bond performance of concrete with only 50% fly ash replacement using a pullout test. The study concluded that bond strength of the 50% fly ash was very close to that resulted from testing CC. In addition, in 2014, Arezoumandi et al. conducted another HVFA concrete bond assessment using mild steel reinforcement with three types of concrete which were 0.0%, 50%, and 70% cement replacement with fly ash-class C [12]. Their investigation concluded that bond strength increases by increasing the level of fly ash. In 2018, Al-Azzawi et al. [13] investigated the bond strength of fly ash-based geopolymer with steel reinforcement using a pullout test. Five different sources of fly ash class F were studied including: 300, 400, 500 kg/m^3 (18, 25, 31 lb/ft^3), and different proportions of alkaline activator were prepared. The investigation found that the fly ash properties including distribution of particle size and the content level of silica, alumina, and calcium oxide affected