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Effect of Virgin Polypropylene Fibers and HRWR on the Workability and Strength of Fiber-Reinforced Concrete

Krishana Wadhwani[1], Anil Kumar Sharma[2]

M.Tech Student, Department of Civil Engineering, Arya Institute of Engineering & Technology, Jaipur, Rajasthan, India[1]

Assistant Professor, Department of Civil Engineering, Arya College of Engineering, Jaipur, Rajasthan, India[2]

Abstract: Fiber-reinforced concrete (FRC) has gained significant attention in recent years due to its enhanced performance compared to conventional concrete. However, fire resistance remains a critical concern, especially when FRC is used in residential, municipal, and other structural applications. The performance of FRC under fire conditions varies depending on fiber types, fiber configurations, and the cement matrix composition. This paper presents a comprehensive review of recent research on the fire resistance of FRC. Key temperature-dependent parameters such as permeability, delamination, compressive strength, tensile strength, modulus of elasticity, and strength loss ratio have been studied for steel fiber-reinforced, polypropylene fiber-reinforced, and hybrid fiber-reinforced concrete. Additionally, current policies and guidelines related to FRC are discussed. In the present experimental study, two different types of virgin polypropylene fibers were used in the preparation of concrete samples. One of the fibers, BC-48 (a type of virgin polypropylene), was incorporated as a cement substitute. High-Range Water-Reducing Admixture (HRWR) was also added to the mixes in varying proportions of 0.0%, 0.2%, and 0.4%. Virgin polypropylene fibers were used in varying amounts: 0.0%, 0.3%, 0.6%, 0.9%, 1.2%, and 1.5% by weight of cement. The prepared concrete samples were tested for key parameters such as workability and compressive strength to evaluate their performance.

Keywords: FRC, Concrete, Virgin Polypropylene, Cement.

I. INTRODUCTION

Portland cement is very malleable, but weak from stress and cracking [1]. Weaknesses and stresses can be prevented by using standard steel reinforcements mixed to some extent with various special fibers [2]. The addition of fiber increases the strength of the fiber matrix composite, which will change its behavior after failure. The purpose of this document is to provide information on the quality and compatibility of common fibers and their use in the production of concrete with specific properties. A new type of fibrous concrete is made from cellulose fibers [3]. Fiber is a smart little power source made from a variety of materials, including steel, plastic, glass, carbon, and natural materials, and comes in a variety of shapes and sizes.

II. FIBER REINFORCED CONCRETE (FRC)

Fiber-reinforced concrete is a cementitious mixture, aggregate or compact, mixed with suitable, discrete, well-defined and well-dispersed fibers. There are many types and levels of fiber, each with its own benefits. The various fibers do not include continuous nets, braids, cables or long bars. Fibers are little things that make them strong with special properties [4]. They can be round or flat and come in a variety of shapes and sizes. Aspect ratio is a useful parameter commonly used to characterize cables. The diameter of a fiber is the ratio of its length to its diameter. The proportions are generally between 30 and 150. FRC is a type of concrete with fibrous material to increase its strength properties. It is made up of small insulating fibers that continuously distribute and rotate randomly. Fibers include metallic fibers, glass fibers, synthetic fibers and natural fibers [5]. The properties of fiber reinforced materials depend on the materials used, the fiber materials, the shape, distribution, orientation and density of these different fibers. Shotcrete supports multiple threads and can be used with a normal computer. Traditional concrete floors are often used for flooring and walkways, but can be used for a variety of other building materials. (Beams, fixtures, foundations, etc.) Alone or in combination with hand-bonded rebar, fiber concrete (usually steel, glass, or "plastic") is ten times cheaper than rebar [6]. The shape, size and length of the fiber are important. Short fibers, such as short-hair glass fibers, are only effective in the first few hours after the concrete is poured (reducing shrinkage as the concrete hardens), but they do not increase the concrete's tensile strength.

III. METHODOLOGY

Mix Design for M 35 Grade of Concrete

Step 1: Target mean strength

$f_t = f_{ck} + K.S.$

Where,

f_t = target average compressive strength at 28 days,

f_{ck} = characteristic compressive strength at 28 days,

s = standard deviation

$f_t = 35 + 1.65*5$

$f_t = 43.25$ N/mm^2

Step 2: Water cement ratio

W/c ratio = 0.45 {From SP 23, Table 31}

This is equal to 0.45 (severe condition), so it is ok.

Step 3: Weight of water

W_w = 186 litre {From Table 4 of IS: 10262-2019, Coarse aggregate= 20mm}

For 100 mm slump,

$W_w = 186 + 186 * (6/100)$

W_w= 197.16 kg/m^3

For use of plasticizer

$W_w = 197.16 – 197.16 * (8/100)$

W_w = 181.37 kg/m^3

This value is maximum limit, so we will take value based on experience

W_w = 181.38 kg/m^3

Step 4: Cement Content

W_c = Ww/ w/c

= 181.38/0.45

= 403.06 kg/m^3

This is greater than 320 kg/m^3 (severe) so, it is ok.

W_c = 403.06 kg/m^3

Step 5: Proportion

Proportion = 0.6 {from table 5 of IS 10262-2019, Coarse aggregate = 20mm, Zone I}

For w/c = 0.44

Proportion = 0.6 + (2*0.01) = 0.62

Step 6: Quantity of Fine aggregate and coarse aggregate

Total volume of concrete = 1m^3

a. Volume of concrete mass = 1- air content

= 1 -1 * (1.5/100)

= 0.985 m^3

b. Volume of cement = W_c/ (S_c*1000)

= 403.06/ (3.15*1000

= 0.127 m^3

c. Volume of water = $W_w/1000$
$= 181.38/1000$
$= 0.181\ m^3$

d. Volume of admixture = $W_{adm}/ (S_{adm} *1000)$
$= (403.06/1000)/ (1.145*1000)$
$= 0.00035\ m^3$

e. Volume of total aggregate = a – (b+c+d)
$= 0.985 – (0.135+0.181+0.00035)$
$= 0.6686\ m^3$

f. Weight of coarse aggregate = Proportion * e * S_{ca} * 1000
$= 0.62*0.6686*2.67*1000$
$= 1106.8$ kg

g. Weight of Fine aggregate = (1- proportion) *e* S_{fa} *1000
$= (1-0.62) *0.6686*2.65*1000$
$= 673.280$ kg

IV. RESULT AND DISCUSSION

Table 1: Slump Flow Value with Virgin Polypropylene and 0.0% HRWR-Super Plasticizer

Mix	HRWR (SP)	Virgin Polypropylene	Slump Flow (mm)
Mix-1	0.0%	0.0	577
Mix-2	0.0%	0.3	677
Mix-3	0.0%	0.6	622
Mix-4	0.0%	0.9	412
Mix-5	0.0%	1.2	192
Mix-6	0.0%	1.5	77

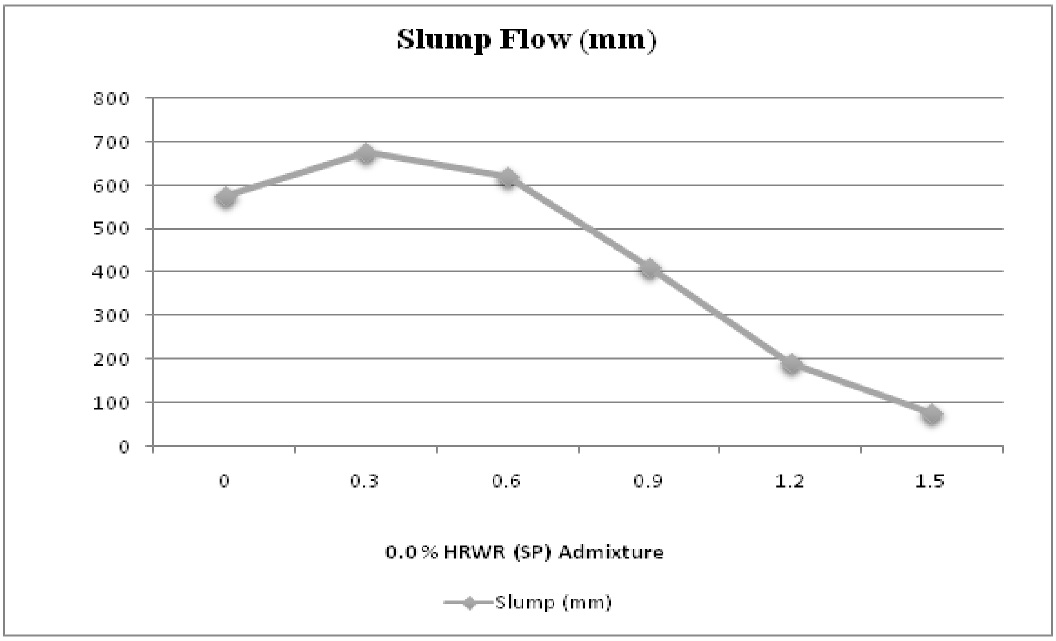

Fig 1: Slump Flow Value with Virgin Polypropylene and 0.0% HRWR-Super Plasticizer

Maximum value of Slump flow test for 0.0% HRWR Super Plasticizer as admixture and varying of Cement substitute with Virgin Polypropylene is 577mm after addition of HRWR and virgin Polypropylene this will reduced to 77mm in mix-6.

Table 2: Slump Flow Value with Virgin Polypropylene and 0.2%HRWR-Super Plasticizer

Mix	HRWR (SP)	Virgin Polypropylene	Slump Flow (mm)
Mix-1	0.2%	0.0	575
Mix-2	0.2%	0.3	675
Mix-3	0.2%	0.6	620
Mix-4	0.2%	0.9	410
Mix-5	0.2%	1.2	190
Mix-6	0.2%	1.5	75

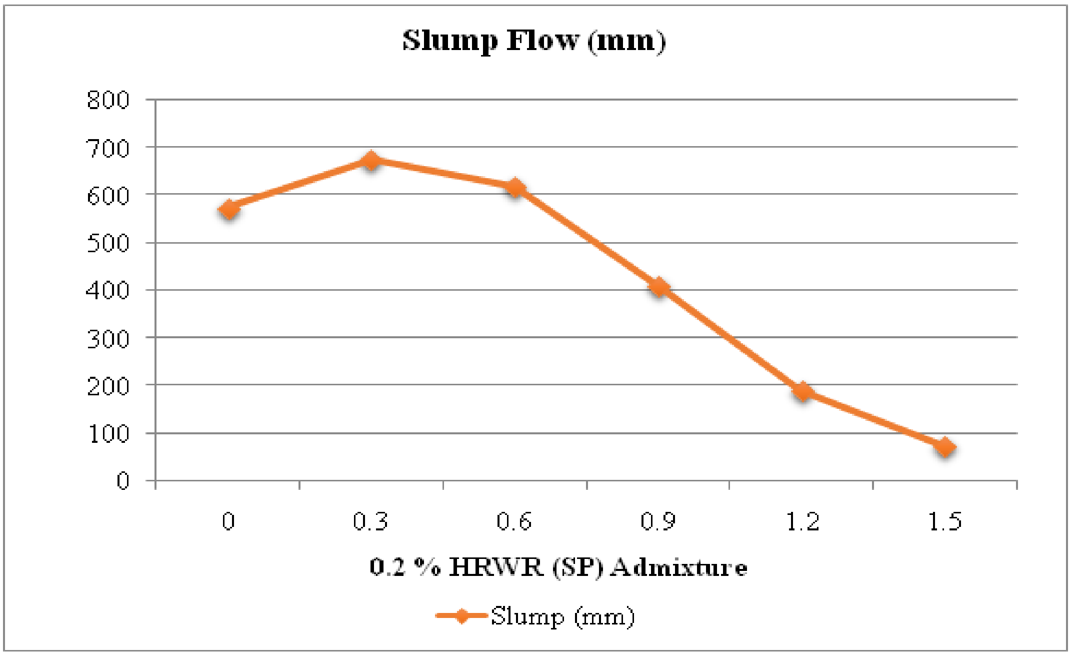

Fig 2: Slump Flow Value with Virgin Polypropylene and 0.2%HRWR-Super Plasticizer

Maximum value of Slump flow test for 0.2% HRWR Super Plasticizer as admixture and varying of Cement substitute with Virgin Polypropylene is 575mm after addition of HRWR and virgin Polypropylene this will reduced to 75mm in mix-6.

Table 3: Slump Flow Value with Virgin Polypropylene and 0.4%HRWR-Super Plasticizer

Mix	HRWR (SP)	Virgin Polypropylene	Slump Flow (mm)
Mix-1	0.4%	0.0	572
Mix-2	0.4%	0.3	672
Mix-3	0.4%	0.6	617
Mix-4	0.4%	0.9	407
Mix-5	0.4%	1.2	187
Mix-6	0.4%	1.5	72

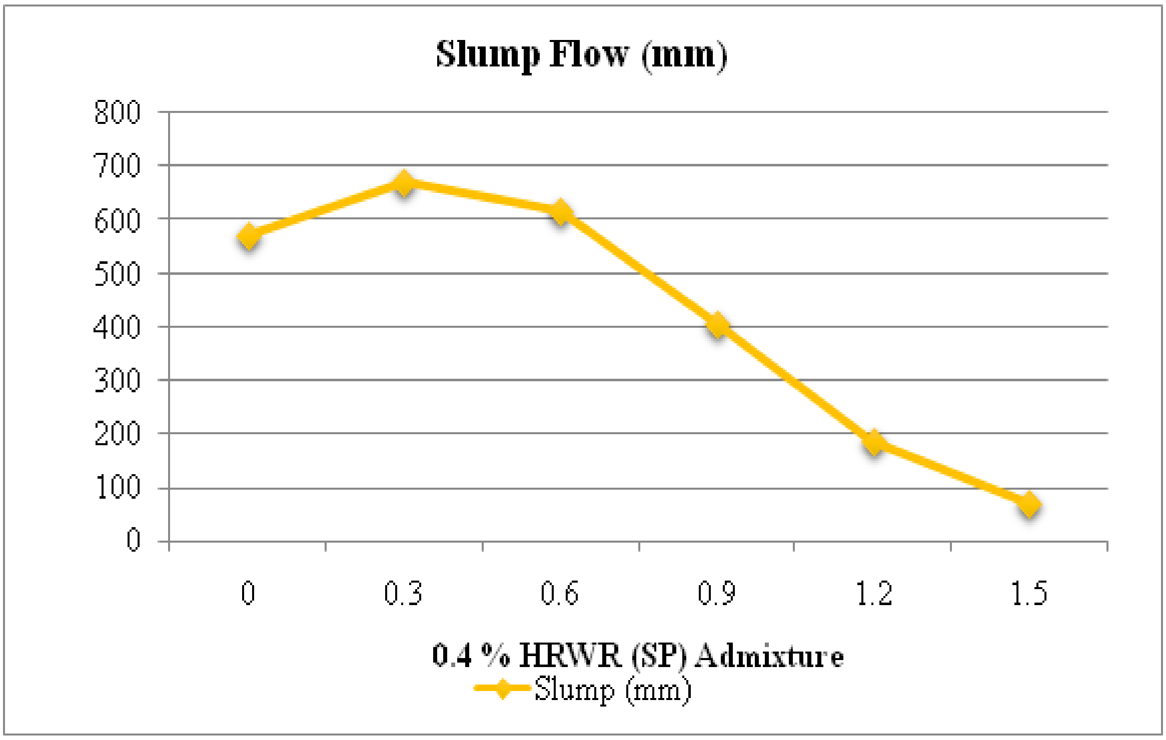

Fig 3: Slump Flow Value with Virgin Polypropylene and 0.4%HRWR-Super Plasticizer

Maximum value of Slump flow test for 0.4% HRWR Super Plasticizer as admixture and varying of Cement substitute with Virgin Polypropylene is 572mm after addition of HRWR and virgin Polypropylene this will reduced to 72mm in mix-6.

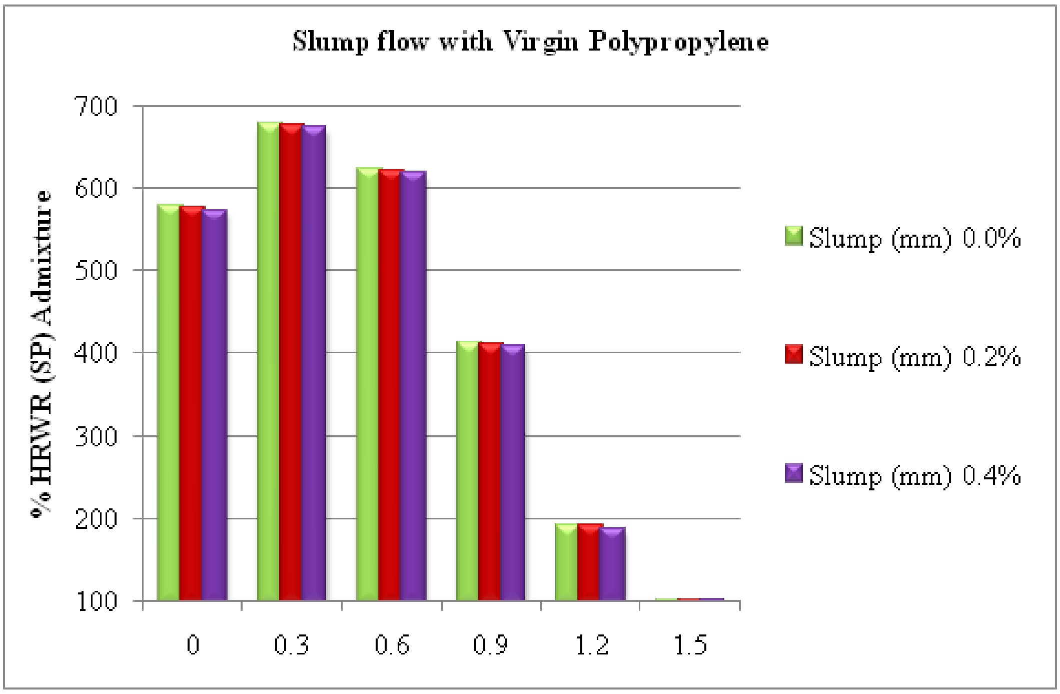

Fig 4: Slump Flow Value with Virgin Polypropylene and 0.0%, 0.2% and 0.4% HRWR-Super Plasticizer

V. CONCLUSION

The experimental study revealed that the incorporation of Virgin Polypropylene fibers and HRWR Super Plasticizer significantly influenced the workability and mechanical properties of concrete. The slump flow values showed a decreasing trend with the addition of HRWR and fibers across all mixes, indicating reduced workability. Notably, Mix-6 exhibited the lowest slump flow values for all HRWR dosages, with a maximum reduction from 577 mm to 72 mm. Conversely, compressive strength improved with the inclusion of HRWR and fibers. At 7, 14, and 28 days, the compressive strength increased consistently across all HRWR dosages, with Mix-2 and Mix-3 showing the highest values reaching up to 48.25 N/mm² at 28 days for 0.4% HRWR. Similarly, enhancements were observed in flexural and indirect tensile strengths, with the maximum values recorded in Mix-3. Flexural strength increased up to 5.660 N/mm² and indirect tensile strength reached 4.468 N/mm² for 0.4% HRWR at 28 days. These results confirm that the combined use of Virgin Polypropylene fibers and HRWR Super Plasticizer improves the strength properties of concrete while affecting its workability.

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