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MECHANICAL PROPERTIES OF MRP LIGHTWEIGHT CONCRETE AND EFFECT OF COMPRESSIVE STRENGTH ON SHEAR CAPACITY OF BEAMS

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Abstract: The objective of this study is to investigate the effect of compressive strength on the shear capacity of Modified Reactive Powder Lightweight Concrete (MRPLWC) Beams. The structural behavior of (3) MRPLWC beams without web reinforcement under two point loading system , are studied. Three percentage of Silica Fume (SF) were used to improve the compressive strength of MRPLWC. The experimental results pointed that a positive correlation between the compressive strength and diagonal cracking load and ultimate shear load. Increasing the compressive strength from (89.53 MPa) to (90.3) MPa lead to increase the diagonal cracking load V_{cr} and increasing ultimate shear load V_u **.**

Keywords: *Compressive Strength , Shear Strength , Diagonal Cracking Load ,Ultimate Load*

الخواص الميكانيكية للخرسانة المصنعة من خرسانة المساحيق الفعالة المعدلة الخفيفة الوزن وتأثير مقاومة الانضغاط على سعة القص

الخلاصة: الغرض من هذه الدراسة هي للتحقق من تأثير مقاومة الانضغاط على مقاومة القص للعتبات الخرسانية المصنعة من خرسانة المساحيق الفعالة المعدلة الخفيفة الوزن.حيث تم دراسة سلوك ثلاث اعتاب بدون حديد القص و تحت تأثير قوتين مركزيتين. ثلاث نسب من غبار السيلكا الفعالة تم اعتمادها لتحسين مقاومة الانضغاط.النتائج المختبرية اعطت مقارنة ايجابية بين مقاومة الانضغاط و حمل التشقق الاول وحمل القص الاقصى. زيادة مقاومة الانضغاط من 89.53 الى 90.3 ميكاباسكال يؤدي زيادة حمل التشقق الاول V_{cr} و زيادة الحمل الاقصى للقص V_u .

1. Introduction

RPC otherwise known as Ultrahigh Performance Concrete UHPC , which is developed in twenty century by French company .In form of super plasticizer, SF - cement mixture " low w/b (cement + silica fume) ratio which ranges between(0.15 to 0.25) " (Anila and Mathew; 2015) [1] , with very low w/c ratio " decrease w/c while improving the workability of concrete .

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"(Raj and Kumar ; 2015) [2] very fine quartz sand (0.15 - 0.6) instead of ordinary aggregate and steel fiber "fibers are incorporated in RPC to improve the fracture properties of the composite " (Khalil , ;2012) [3] . "

Adding steel fibers can greatly enhance its bending strength, tensile strength, toughness and impact resistance " [1] . RPC has high strength ranging between (120 to 800) MPa. Cement factor in RPC is high (900 to 1000) kg/m^3 the cement factor increases the creep strain and drying shrinkage of the RPC relative to traditional concrete with a cement factor usually in order (300 to 500) kg/m^3 . Actually, and due to the absence of coarse aggregate we can say RPC is not a concrete.

MPRC produced by replacing a fraction of quartz sand by crushed graded aggregate less than (8 mm size) to reduce cost of RPC and to produced high strength exactly in RPC

(Collepardi ;1997) [4] " reported that replacing of fine quartz sand (0.15-0.4 mm) with the same volume of natural aggregate (less than 8 mm size) did not change the compressive strength of RPC at the same W/C ".) These results could not be accept with the model suggested by (Richared and Cheyrezy ; 1995) [5] ".They attributed of high compressive strength of RPC to the better homogeneity of the mixture without coarse aggregate. "

2. Experimental Program

The experimental program included casting and testing three lightweight MRPC beams without web reinforcement. The specimens were designed to fail by diagonal tension (shear) in the web region. All tested beams were simply supported and subjected to two point loads Fig.(1) Each beam had 1200 mm total length and 1100 mm clear span between the supports. The beam dimensions and details are shown in Fig.(1)

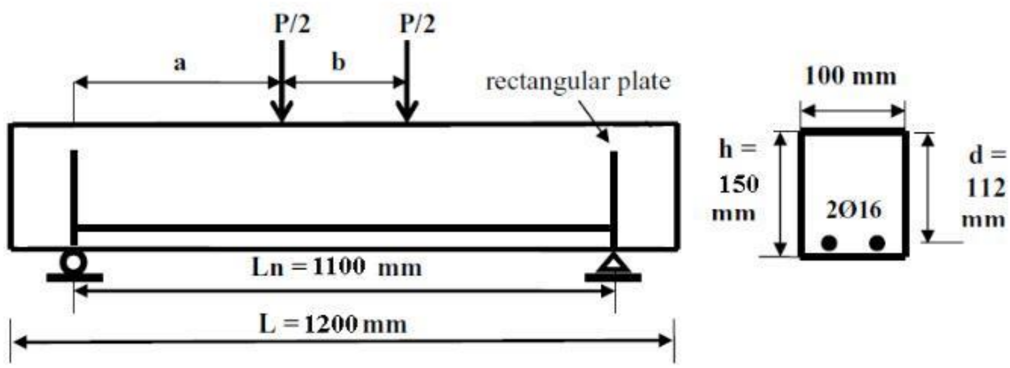

Fig .(1): Details of a Typical Test Beam.

3. Materials

Locally produced ordinary Portland cement manufactured in Iraq was used throughout this work. The compressive strength at 3 days and 7 days are 24 MPa and 29

MPa, respectively. The blain fineness is 2650 cm^2/gm . In this work fine silica sand known as glass sand was used as fine aggregate with size (0.15-0.6) .The sulfate content is 0.35 %, specific gravity is 2.9 and absorption is 0.71%.The coarse aggregate used in this work was porecilenite which classified as lightweight aggregate in order to get modified reactive powder concrete .Porecilenite is a type of stone of white color . At first, the stone crushed by crusher machine at material laboratory in College of Engineering at Mustansiriyah University. The specific gravity is 1.46 and the absorption equal to 35%. Locally produced silica fume (SF) was used throughout this work. According to the manufacturer, the powder had a moisture content of 0.68% and specific surface area of 20 m^2/gm. Flocrete PC260 admixture was used as a high range water reducer conforming to ASTM C 494 (types A and G) [9]. The admixture is a Light-yellow liquid with a specific gravity of (1.1±0.02) at 25 °C. The steel fiber used to improve the mechanical properties , were of 0.2 mm diameter, 13 mm length, of 65 aspect ratio (L/D) and density of 7830 Kg/m^3. Also high tensile deformed steel bars (of 16 mm and 20 mm nominal diameters) were used as tension reinforcement. The bars had a yield strength of 507 MPa for 16 diameter bar mm and 496 for 20 mm diameter bar.

4. Mixes , Mixing Procedure

Three type of lightweight MRPC mixes were used in the present work as listed in Table (1) the variable used in these mixes were ratio of silica fume as additives were studied 5% , 10 % and 15 % constant of volume fraction of fiber V_f=1.0 .

Table (1) Mixes Properties of MRPC.

Mix Type	Cement Kg/m^3	Sand Kg/m^3	Coarse Aggregate (Porcelnite)%****	SF %*	**Flocrete PC 260 %	W/C	Fiber Content***
M1-5	900	900	50	5	5	0.2	1.0
M1-10	900	900	50	10	5	0.2	1.0
M1-15	900	900	50	15	5	0.2	1.0

*Percent of cement weight.
**Percent of binder (cement + silica fume) weight.
***Percent of mix volume.
**** Percent of fine aggregate

Initially small trial batch mixing was prepared using rotary mixer of o.15 m^3 capacity at material laboratory in college of engineering at Mustansiriayah University Mixing sequence was as follows:

1. Before using mixer to mix concrete any remaining concrete from previous batch was removed and cleaned off and saturated the mixer , later to ensure uniform distribution of the modified reactive powder particle the SF powder was mixed in dry state with required amount of cement for (5) minutes , after this time the amount of sand and porecilenite was added to mixer and mixed it for 5 minutes
2. Mix 1/3 of superplastizer with water and added to the mixer slowly.

3. The another of 1/3 of superplastizer was added to mixer and let go the mixer rotary for (5-10) minute.
4. In addition hand mixing was done after adding the required quantity of superplastizier to prevent any segregation.
5. At end added steel fiber slowly to mixer and added the last of a superplastizier and mixing for 5 minutes.

6. Mechanical Properties of Hardened Concrete

Four main properties of hardened lightweight MRPC were identified for each beam, called, compressive strength f_{cu} ,indirect tensile strength f_t, modulus of rupture f_{rpf} and modulus of elasticity E_c . An average value of three control specimens was considered representative of the specified mechanical properties of lightweight MRPC.

A. Compressive Strength f_{cu}

The compressive strength (f_{cu}) tests were performed on 100 mm MRPC cube . For constant V_f of 1.0 % and an increase in silica fume content from 5 % to 10 % and 15% lead to an increase in compressive strength from 81.9 MPa to 89.53 MPa and 90.3 MPa with increasing percentage from 0.0 to 9.32% and 10.26 % respectively as Fig.2 . This value indicate to the increasing the percentage of SF content on the compressive strength of lightweight .

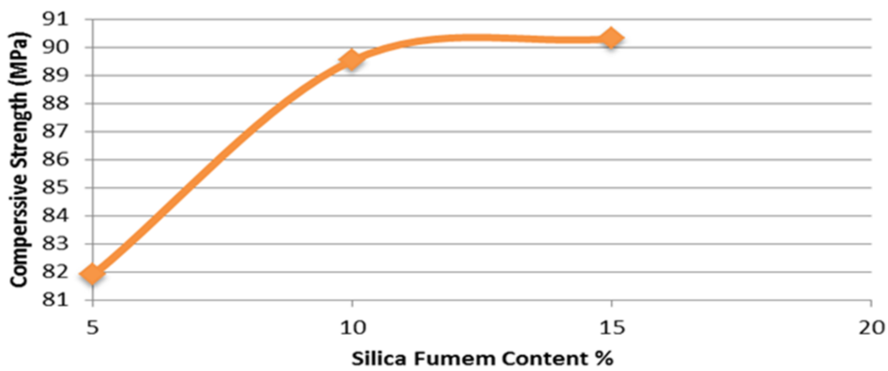

Fig. (2) Effect of SF Content on Compressive Strength

B. The Indirect Tensile Strength f_t

It was used to determine the tensile strength of lightweight MRPC mixes since the direct method has some difficulties, such as the problem of clamping the sample and the problem caused by the particle shape of the sample. The Indirect tensile strength f_t tests were performed on (100 *200) mm concrete cylinders. Increasing SF content from 5 % to 10 % and 15 % with V_f =1.0 % the compressive strength increase from 8.8 to 9.12 and 9.7 MPa resulted in 3.64 % and 10.23% increase in splitting tensile strength respectively as shown in Fig. 3

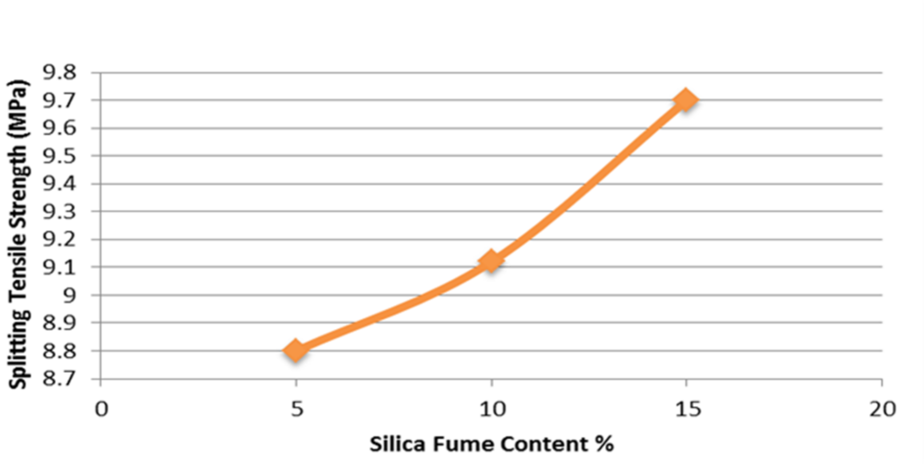

Fig. (3) Effect of SF Content on Indirect Tensile Strength

C. Modulus of Rupture f_{rpf}

In this work, the modulus of rupture f_{rpf} test was carried out on (100 *100* 500) mm prisms subjected to two point loading . The flexural tensile strength is evaluated by assuming liner stress distribution across the cross section is invariably higher than that observed from direct tensile test Increasing SF content from 5 % to 10% and 15% with V_f = 1.0 respective the modulus of rupture increase from 11.2 to 13.9 and 14.8 MPa resulted of 24.11% and 32.14 % in flexural tensile strength was obtained as Fig.4

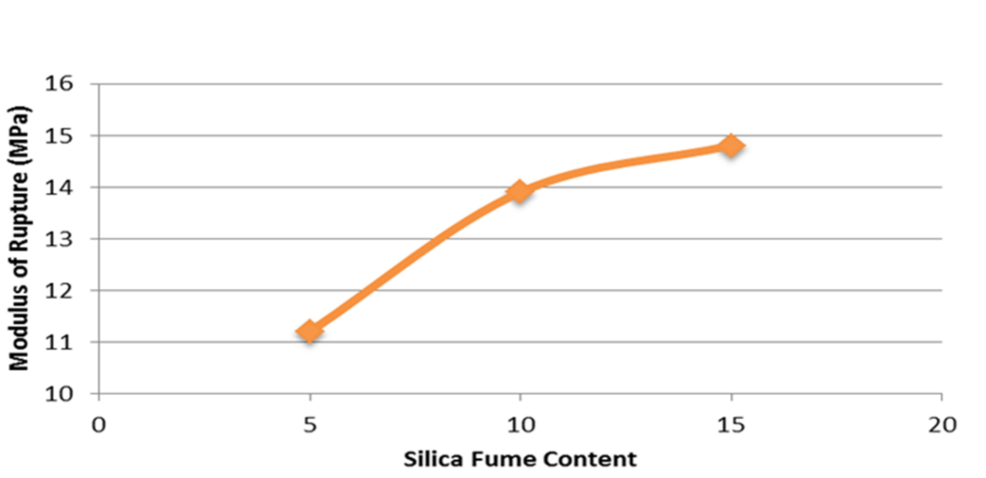

Fig (4) Effect of SF Content on Modulus of Rupture

D. Modulus of Elasticity E_c

The modulus of elasticity carried out on (150*300) mm concrete cylinder. Increasing SF from 5 % to10 % and 15% with V_f =1.0 % the modulus of elasticity increased from 39.1 to 40.47 and 42.12 GPa with increasing percentage from 0.0 to 3.5 % and 7.72 % respectively. These values indicate that there is a significant effect for increasing SF content on the modulus of elasticity of lightweight MRPC Fig.5

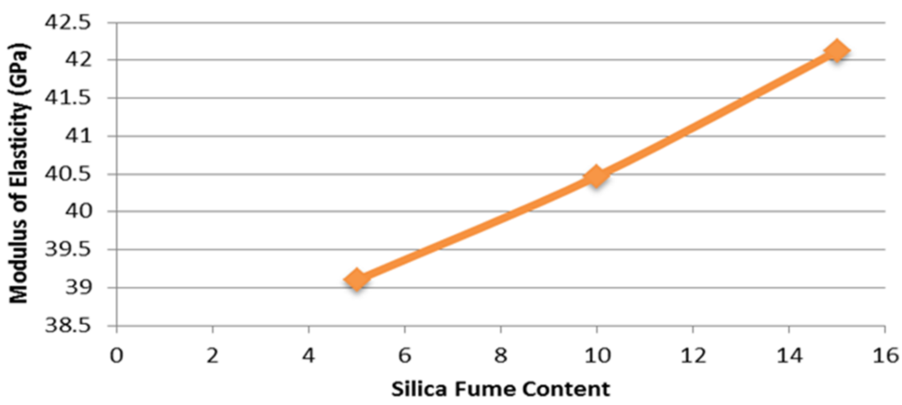

Figure (5) Effect of SF Content on Modulus of Elasticity

7. Testing Procedure

All beams and control specimens were removed from the curing water tank at the age of 28 days. Before testing, the beam was cleaned and painted white to allow easy detection of crack propagation. The beam was placed on its supports in the machine with a clear span of 1100 mm. The test of lightweight MRPC beams as shown in Plate (1). All beam were tested as simply supported beams under two point load .

The dial gage was placed in its position touching the bottom surface of the beam at mid-span The load was applied up to failure. The first crack load was recorded as a load at which the first crack was observed. Mid span deflection of the tested beam was recorded every 10 kN using a dial gauge.

Plate (1) Testing lightweight MRPC Beams

8. Shear Strength of Lightweight MRPC beams

To study the effect compressive strength of concrete on the shear strength of lightweight MRPC beams , three percentage of silica fume (5 % ,10 % and 15 %) were adopted .The experimental test results from this investigation are shown in Fig.

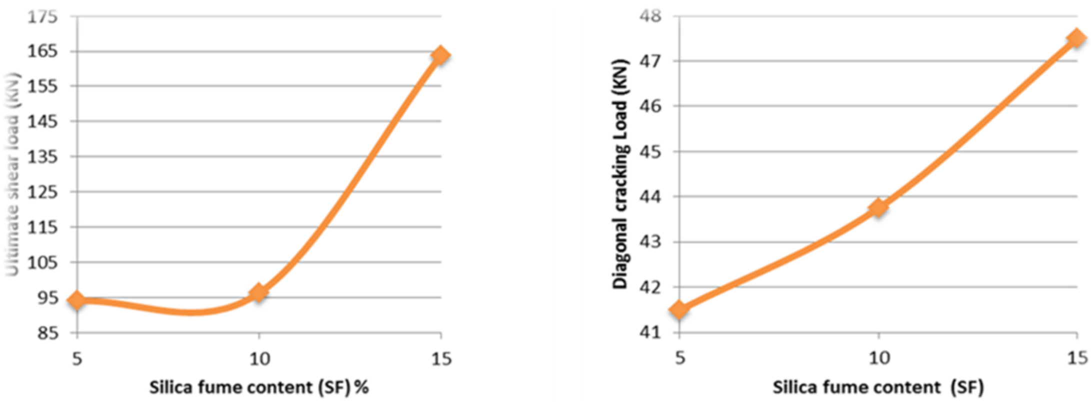

Fig. (6) Effect of SF Percentage of Shear Strength of MRPC beams

Fig. (6) shows the shear strength verses the content of silica fume curves of lightweight MRPC beams B5, B3, and B6 with percentage of silica fume ratio of 5 % , 10 %, and 15 % respectively. For values of V_f =1.0 % , a/d= 3.5 and p_w =0.0329 , it was observed that increasing SF from 5 % (81.9 MPa) for B5 to 10 % (89.53 MPa) for B3 and 15% (90.3MPa) for B6 increased cracking load (V_{cr}) from 5.4% to 14.46 % respectively. The ultimate shear capacity V_u was also increased from 2.4% for B3 and 74.2 % for B6 .This increasing is attributed to the fact that the increase in the percentage of SF in MRPC matrix enhanced the steel fiber-matrix bond characteristics due to the interfacial-toughening effect upon fiber slip. This effect of (SF) results in densification of the MRPC matrix, which comes from the enhanced particle packing، this leads to improving the microstructure of MRPC matrix and increase its density.

9. Load-Deflection Behavior

Fig. (7) show the effect of three percentage of silica fume SF (5 % , 10 % and 15 %) on the load deflection behavior of lightweight MRPC beam. It clear from Figure that for the deflection ($\Delta_\circ$) decrease with increase in SF content under constant load. This behavior related to improve particle packing density and intensive chemical reaction due to a pozzolanic reaction with silica hydrate conversion which lead to increasing bond between steel fiber and MRPC matrix so any increase in SF content lead to enhanced the crack control and decrease the deflection of lightweight MRPC beam as same load . Figure (7) shows increase in SF from 5 % for B5 to 10 % for B3 and 15 % for B6 the deflection at ultimate load increase of 3.45 % for B3 and 106.9 % for B6 compared with and the ductility ratio increase with increasing SF content .The Ductility ratio increase by about 26.43 for B3 and 134.4 % for B6 compared to B5

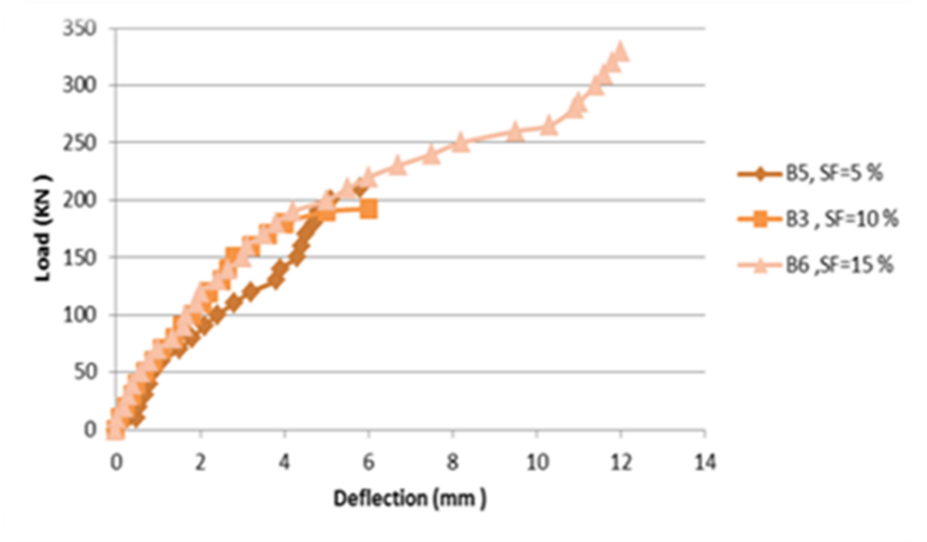

Fig.(7) Effect of SF Content on Mid-Span Deflection Curves
of MRPC beams

10. Crack Pattern

All the beams tested in this work failed in shear although the mode of failure failed in diagonal tension with the exception of B6 had failed in shear -flexural failure.

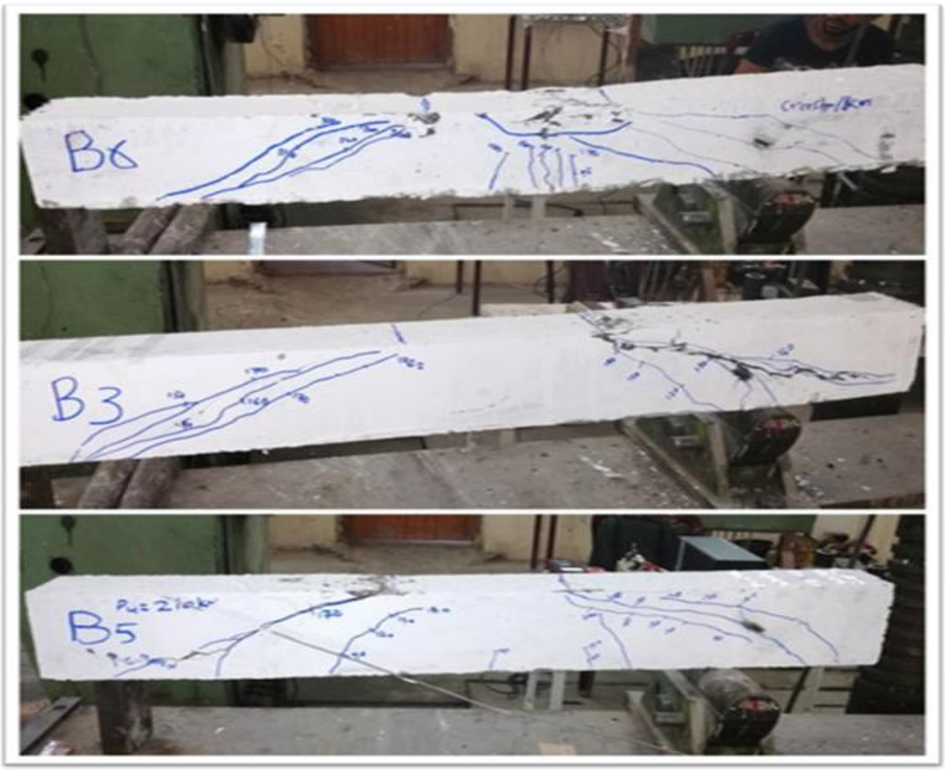

Plate (3) Crack Pattern of Beams

11. Conclusions

1. Increasing the silica fume content SF from 5% to 10% and 15 % in lightweight MRPC beams increased the diagonal cracking load 5.4 % and 14.46 respectively and the ultimate load by 2.4 % and 74.2 % respectively.
2. Increase silica fume in lightweight MRPC beam results in enhanced ductility
3. Increasing SF from 5 % to 10 % and 15 % the deflection at ultimate load increase of 3.45% and 106 % respectively and for same increase the ductility ratio increase by about 26.43% and 134.4 % respectively.
4. The mode of failure is effected by SF content if increase the SF content from 10 % to 15% with (V_f =1.0 , pw =3.29 % , a/d =3.5) the mode of failure change from diagonal tension failure to shear –flexural failure.

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