An Experimental Investigation on Strength Properties of stainless Steel Fiber Reinforced Concrete Beam Elements

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Abstract- Concrete is the most generally utilized construction material since it can be cast into any alluring shape. Ductility and energy absorption capacity are the fundamental necessities of earthquake resistant structures. However, the traditional concrete has low rigidity, inferior energy absorption and little protection from cracking. As a result, it can't satisfy the prerequisites of the earthquake or seismic resistant structure. Widespread researches have demonstrated that the most noteworthy impact of the incorporation of steel fiber in concrete is to defer and control malleable splitting of the composite material in which essential factors are fiber content and matrix composition. The addition of steel fiber to matrix improves various properties of concrete. In this experimental study the strength properties are determined by utilizing different geometrical stainless steel fibers. The different parameters like load carrying capacity, stiffness, ductility and energy absorption capacity were analyzed for better understanding of behavior of stainless steel fiber in concrete.

Keywords: Ductility, Steel Fiber, Load Carrying capacity, Energy absorption capacity.

I.INTRODUCTION

Addition of short, discontinuous fibers plays an important role in the improvement of the mechanical properties of concrete. It increases elastic modulus, decreases brittleness; controls crack initiation, and its subsequent growth and propagation. Deboning and pull out of the fibers require more energy absorption, resulting in a substantial increase in the toughness and fracture resistance of the material to cyclic and dynamic loads. In particular, the unique properties of steel fiber reinforced concrete SFRC suggest the use of such material for many structural applications, with and without traditional internal reinforcement. The use of SFRC is, thus, particularly suitable for structures when they are subjected to loads over the serviceability limit state in bending and shear, and when exposed to impact or dynamic forces, as they occur under seismic or cyclic action.

Properties of SFRC in both the freshly mixed and hardened state, including durability, are a consequence of its composite nature. The mechanics of how the fiber reinforcement strengthens concrete or mortar, extending from the elastic pre-crack state to the partially plastic post-cracked state, is a continuing research topic. One approach to the mechanics of SFRC is to consider it a composite material whose properties can be related to the fiber properties (volume percentage, strength, elastic modulus, and a fiber bonding parameter of the fibers), the concrete properties (strength, volume percentage, and elastic modulus), and the properties of the interface between the fiber and the matrix.

A more general and current approach to the mechanics of fiber reinforcing assumes a crack arrest mechanism based on fracture mechanics. In this model, the energy to extend a crack and deboned the fibers in the matrix relates to the properties of the composite

A. Stainless Steel Fibers

It is defined as a steel alloy with a minimum of 10.5% to 11% chromium content by mass. Stainless steel does not readily corrode, rust or stain with water as ordinary steel does, but despite the name it is not fully stain-proof, most notably under low oxygen, high salinity, or poor circulation environments. It is also called **corrosion-resistant steel** or **CRES** when the alloy type and grade are not detailed, particularly in the aviation industry. There are different grades and surface finishes of stainless steel to suit the environment the alloy must endure. Stainless steel is used where both the properties of steel and resistance to corrosion are required.

Stainless steel differs from carbon steel by the amount of chromium present. Unprotected carbon steel rusts readily when exposed to air and moisture. This iron oxide film (the rust) is active and accelerates corrosion by forming more iron oxide, and due to the dissimilar size of the iron and iron oxide molecules (iron oxide is larger) these tend to flake and fall away. Stainless steels contain sufficient chromium to form a passive film of chromium oxide, which prevents further surface corrosion and blocks corrosion from spreading into the metal's internal structure, and due to the similar size of the steel and oxide molecules they bond very strongly and remain attached to the surface.

B. Mechanical Properties of FRC

Addition of fibers to concrete influences its mechanical properties which significantly depend on the type and percentage of fiber. Fibers with end anchorage and Properties and Applications of Fiber Reinforced Concrete high aspect ratio were found to have improved effectiveness. It was shown that for the same length and diameter, crimped-end fibers can achieve the same properties as straight fibers using 40 percent less fiber.

a) Compressive Strength

The presence of fibers may alter the failure mode of cylinders, but the fiber effect will be minor on the improvement of compressive strength values (0 to 15 percent)

b) Modulus of Elasticity

Modulus of elasticity of FRC increases slightly with an increase in the fibers content. It was found that for each 1 percent increase in fiber content by volume there is an increase of 3 percent in the modulus of elasticity.

c) Flexure

The flexural strength was reported to be increased by 2.5 times using 4 percent fibers.

d) Toughness

For FRC, toughness is about 10 to 40 times that of plain concrete.

e) Splitting Tensile Strength

The presence of 3 percent fiber by volume was reported to increase the splitting tensile strength of mortar about 2.5 times that of the unreinforced one.

f) Fatigue Strength

The addition of fibers increases fatigue strength of about 90 percent and 70 percent of the static strength at 2 x 106 cycles for non-reverse and full reversal of loading, respectively.

g) Impact Resistance

The impact strength for fibrous concrete is generally 5 to 10 times that of plain concrete depending on the volume of fiber.

II. FINDING FROM LITERATURE REVIEWS

Luke Sultan Yilmaz, Ismail Caritas, Mehmet Kamala and Melt Yasser Kaltakci; Seljuk University, "An experimental study of steel fiber reinforced concrete columns under axial load and modeling by ANN" From the experimental study done and related analytical study, it has been observed that using different amount of steel fiber in concrete only increases the material ductile to some amount but has no significant increase in carrying power of samples tested under axial load. The effects of steel fiber were appeared at the fall down behaviors of the columns. While columns with no fiber present so much crispy behaviors before falling down.

D.D.L CHUNG, "Cement reinforced with short Mild fibers" Short Mild fibro cement-matrix composites exhibit attractive tensile and flexural properties, low drying shrinkage , high specific heat, low thermal conductivity, high electrical conductivity, high corrosion resistance and weak thermoelectric behavior. Moreover, they facilitate the catholic protection of steel reinforcement in concrete, and have the ability to sense their own strain, damage and temperature.

P.U- WOEI CEHN & D.D.L CHUNG, "Mild fiber reinforced concrete as an intrinsically smart concrete For damage assessment for static and dynamic loading" Mild fiber reinforced concrete as an intrinsically smart concrete that can sense elastic deformation, in elastic deformation under tension, compression and flexure. The fibers serve to bridge the cracks and provide a conduction path they do not need to touch one another. At the same fiber volume fraction the presence of coarse aggregate decrease the fractional change in resistance as well as decrease the electrical resistivity. The fractional change at fracture is higher under compression that tension due to higher ductility under compression. Application includes real time damage assessment and dynamic load monitoring.

G CAMPIONE, L LA MENDOLA and G ZINGONE, "Seismic Behavior of Fiber Reinforced Concrete Frames" The nonlinear analysis for framed structures has stressed that comparable ductile behavior can be obtained by using in the critical regions less amount of transverse reinforcement but integrating the concrete with reinforcing fibers. Results have shown that also in the case of HSC members it is possible to achieve a dissipative collapse mechanism in presence of very high values of axial loads, but particular attention must be paid on the P-δ effect that can significantly reduce the bearing capacity and the available ductility of the frames. The analysis carried out here, needs however to examine further aspects as the buckling problem for the longitudinal steel bars, the fixed end rotation effects and the dowel action in the beams.

Padmanabha Rao Tadepalli, Norman Hoffman, Thomas T. C. Hsu, and Y. L. Mo, "STEEL FIBRE REPLACEMENT OF MILD STEEL IN PRESTRESSED CONCRETE BEAMS" The purpose of this research was to study the behavior of Pre-stressed Steel Fiber Concrete (PSFC) panels and beams under shear and to develop a simplified equation for the shear design of pre-stressed concrete girders. The following conclusions were made from this research:

1) Based on the flexural test results of small beam specimens, the recommended maximum dosage of Diamox steel fibers to be used in full-scale PSFC beams considering strength and good workability of concrete mix, is as below:

(a) Diamox Long Fibers - Dosage of 0.5% by volume of concrete

(b) Diamox Short Fibers - Dosage of 1.5% by volume of concrete

2) PSFC panel tests showed that the tensile stiffness and concrete softening characteristics of PSFC improves with an increased Fibre-Factor.

3) With regard to the PSFC panel tests steel fibres causes an increase of concrete compressive strength under sequential loading to determine the constitutive models. In the case ofproportional loading for pure shear testing, a factor We, which is a function of fiber factor (FF) is proposed for incorporation into the softening coefficient of pre-stressed steel fibre concrete. Wf takes care of the effect of amount of steel fibres on concrete compressive strength.

4) The shear behavior of PSFC beams was critically examined by full-scale tests on six TxDOT Type-A beams and six modified Tx-4B20 box-beams with web-shear or flexural-shear failure modes.

5) From the experimental results of six PSFC I-beams, steel fibres were found very effective in resisting the shear loads and mild steel shear reinforcement (stirrups) can be completely replaced with steel fibres.

6) Test results of PSFC box-beams also demonstrated the effectiveness of steel fibres in resisting shear forces. It was also found that local failures in these beams, such as penetration of web shear crack into the top flange, have to be taken care so as to achieve the ultimate shear capacity in the PSFC beam. From the test results of all twelve PSFC beams it was found that 1% by volume of Dramix short steel fibres (ZP 305) was an optimum dosage in pre-stress concrete beams as shear reinforcement.

7) Using the constitutive laws of PSFC established in this research, an analytical model was developed and implemented in a finite element program framework (Open Sees) to simulate the shear behavior of the PSFC beams. Using this computer program, the load-deflection curves of all the beams are simulated with acceptable accuracy.

8) A new shear design equation was developed using the results of the PSFC beam tests performed in this research. Four design examples were presented to illustrate the use of the developed design equations for PSFC girders.

III. EXPERIMENTAL PROGRAM

A. Material Properties

Two standard concrete mixes with and without steel fibers were employed in the study .The material were used : Portland Pozzolona cement conforming to IS 1489(part 1):1991 Locally available river sand conforming to grading zone-II of IS: 383-1970, Crushed natural rock stone aggregate of maximum nominal size of 20 mm ,Steel fiber conforming to ASTM A820-2001, Cero plast 300 super plasticizer conforms to IS: 9103-1999 and Water conforming to as per IS:456-2000.The specific gravity of each component was: Cement 3.15; Sand 2.61; Coarse aggregate 2.69; steel fibers 7.85 g/cm3. The steel fibers were crimped, hooked, Galvanized iron and Stainless steel were used and Elastic modulus of steel = 2.1 x 10^5 Mpa and aspect ratios are 30,50 and 80 respectively.

B. Sample preparation

A mix proportion of 1:1.29:2.7 with suitable water cement ratio to get a characteristic strength of M30 was considered for this study. The exact quantity of materials for each mix was calculated. The parameters varied were fiber length, fiber. The constituent of materials used for making the concrete were tested and the results are furnished in Table1. The cement, fine aggregate, coarse aggregate were tested prior to the experiments and checked for conformity with relevant Indian standards.

TABLE I. Details of constituent materials

Material	**Description**
Cement	Ordinary OPC (43 grade)
Fine Aggregate	River sand falling on zone II
Coarse Aggregate	20mm nominal size aggregate
Mix ratio	1:1.29:2.7
w/c ratio	0.42
% of steel fiber	0.75 of the total volume(constant)
Super plasticizer	Cero plast 300

IV. RESULT AND DISCUSSION

A. Compressive strength

Compressive strength is the most common test conducted on hardened concrete, partly because it is an easy test to perform, and partly because most of the desirable characteristic properties of concrete are qualitatively related to its compressive strength.

The cube specimen is of size 150x150x150mm.the compressive strength of concrete is done by using compressive testing machine.

TABLE II. Cube Compressive strength test results

Specimen	**7days strength in Mpa**	**28 days Strength in Mpa**
Control concrete M30	42.66	47.77
Galvanized iron fiber	46.88	59.99
Crimped fiber	50.66	63.85
Stainless steel fiber	41.99	45.63
Hooked fiber	44.14	49.78

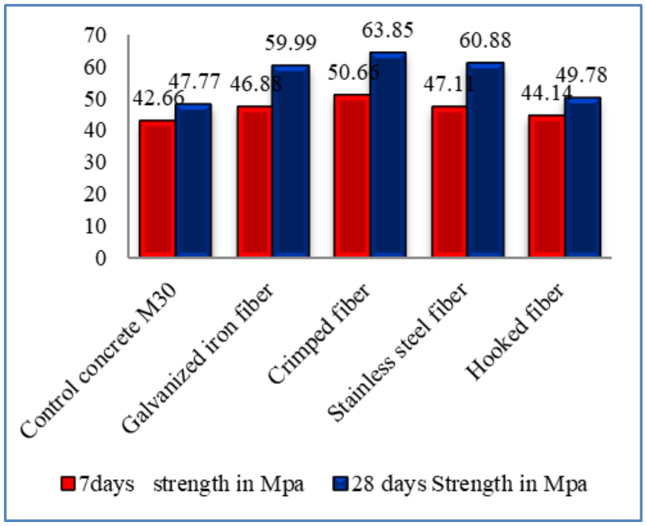

Fig. 1. Cube Compressive strength test results


Fig. 2. Behavior of cube under compression

B. Split tensile strength test results

Cylinder specimens were cast using crimped fiber and stainless steel fiber with 0.75% of total volume.

TABLE III. Split tensile strength test results

specimen	7days strength in Mpa	28 days Strength in Mpa
Control concrete M30	2.54	2.98
Crimped fiber	4.2	4.4
Stainless steel fiber	3.25	3.86

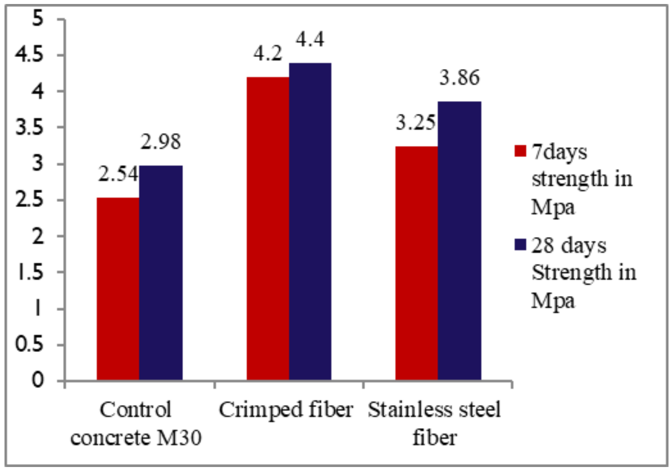

Fig. 3. Split tensile strength test results

Fig. 4. Behavior of cylinder under split tension

C. Cylinder compressive strength

Cylinder specimens were cast using crimped fiber and stainless steel fiber with 0.75% of total volume.

TABLE IV. Split tensile strength test results

specimen	**28days strength in Mpa**
Control concrete M30	25.46
Crimped fiber	33.95
Stainless steel fiber	30.26

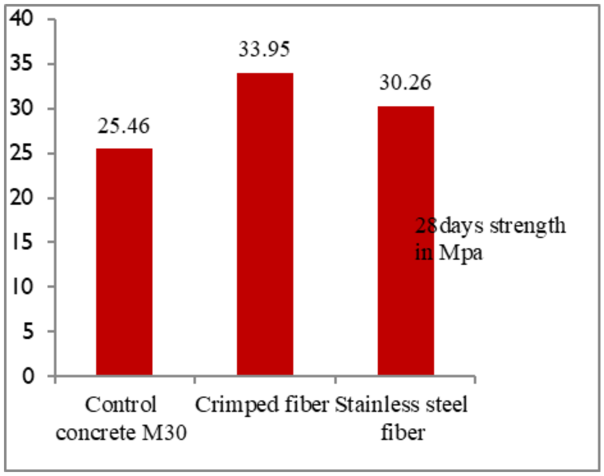

Fig. 5. Cylinder compressive strength test result

Fig. 6. Behavior of cylinder under compression

D. Flexural strength test result

Prism specimens were cast using crimped fiber and stainless steel fiber with 0.75% of total volume.

TABLE V. Flexural strength test result

specimen	**7days strength in Mpa**	**28 days Strength in Mpa**
Control concrete M30	4.02	4.38
Crimped fiber	5.9	6.7
Stainless steel fiber	5.5	6.43

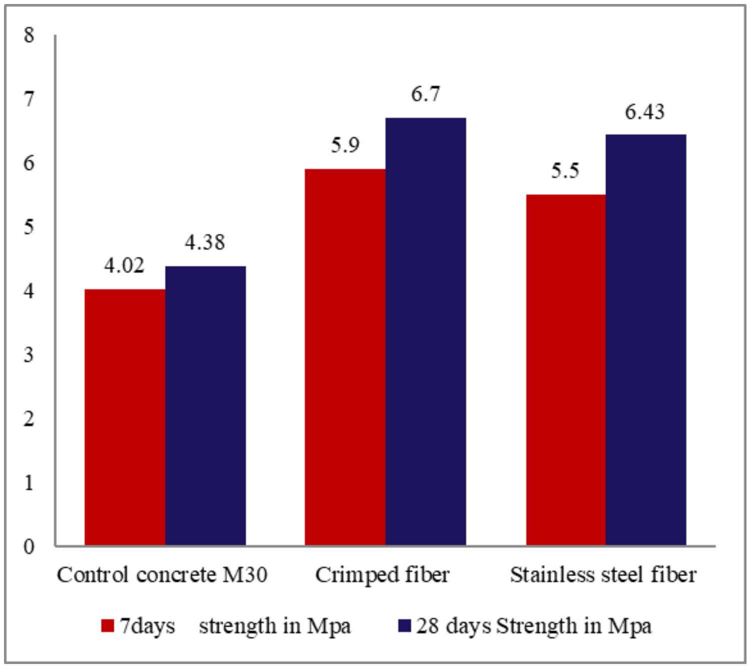

Fig. 8. Flexural strength test result

Fig. 8. Behavior of prism under flexure

E. Load deflection behavior

To study the structural performance of SFRC, SFRC beams of size 100 x 150 x1100mm were cast with crimped and stainless steel fiber and compared with control concrete.

Prism specimens were cast using crimped fiber and stainless steel fiber with 0.75% of total volume.

TABLE V. Flexural strength test result

Fig. 9. Test set up arrangement

TABLE VI. Load deflection behavior of M30 and fibers

S.No	Load (kN)	Deflection		
		M 30	Crimped fiber	Stainless steel fiber
1	0	0	0	0
2	10	0.15	0.5	0.5
3	20	0.60	0.85	0.46
4	30	1.10	1.3	1.2
5	40	1.65	1.7	1.64
6	50	2.20	2.3	2.26
7	60	2.60	3	2.73
8	70	3.40	3.5	3.16
9	71	3.90	3.8	3.54
10	80	-	4.2	3.98
11	90	-	6	4.89
12	91.2	-	6.5	5.46
13	92.5	-	7.4	-

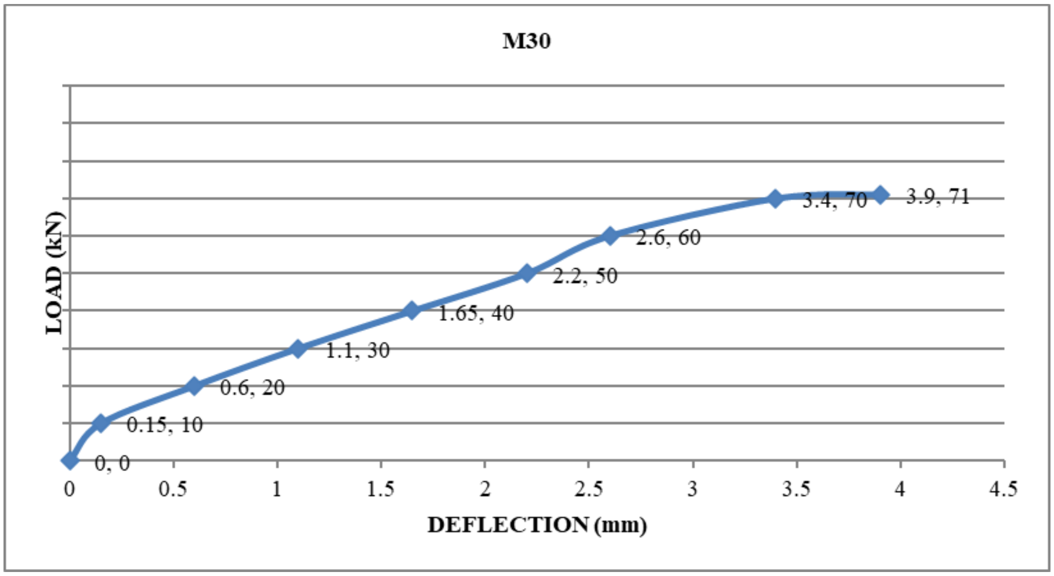

Fig. 10. Behavior of M30 concrete under loading

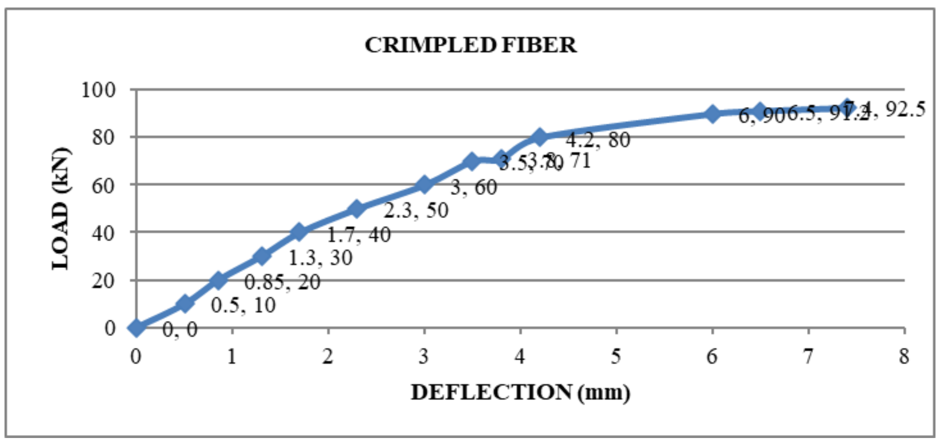

Fig.11. Behavior of crimped fiber under loading

1. The first crack load of SFRC beam is 1.39 times greater than that of RCC beams.
2. The ultimate load carrying capacities of crimped fiber beams are 1.32 times greater than that of RCC beams.
3. The cumulative energy absorption capacity of crimped fiber beam is 2.66 times greater than that of beam –RC.

Crimped and Stainless Steel Fiber Beam

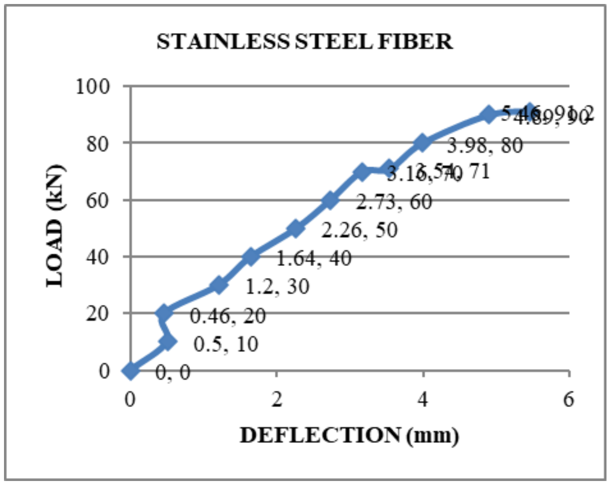

Fig. 12. Behavior of stainless steel fiber under loading

V.CONCLUSIONS

Based on the investigation reported in earlier chapters, the following conclusions are drawn. They are summarized below

RCC and Crimped Fiber Beams

The following conclusions were drawn based on the experimental investigations carried out on RCC beams and crimped fiber beams.

4. The first crack load of SFRC beam is 1.39 times greater than that of RCC beams.
5. The ultimate load carrying capacities of crimped fiber beams are 1.32 times greater than that of RCC beams.
6. The cumulative energy absorption capacity of crimped fiber beam is 2.66 times greater than that of beam –RC.

Crimped and Stainless Steel Fiber Beam

1. The first crack load of crimped fiber beam is 1.1 times greater than that of SSFRC beams.
2. The ultimate load carrying capacities of crimped fiber beams are 1.0 times greater than that of SSFRC beams.
3. The cumulative energy absorption capacity of crimped fiber beam is 1.45 times greater than that of beam –RC.

RCC and Stainless Steel Fiber Beam

1. The first crack load of SSFRC beam is 1.2 times greater than that of RC beams.
2. The ultimate load carrying capacities of SSFRC beams are 1.3 times greater than that of RC beams.
3. The cumulative energy absorption capacity of SSFRC beam is 1.8 times greater than that of beam –RC.

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