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Autor: Gao, Lubin

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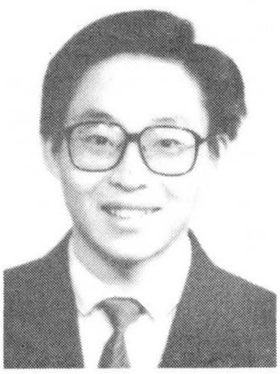
Steel Fibre Reinforced Concrete with Application in Bridge Repair

Application de bétons de fibres d'acier dans la réparation de ponts

Anwendung von Stahlfaserbeton in der Brückensanierung

Lubin GAO
Associate Professor
China Acad. of Railway Sciences
Beijing, China



Lubin Gao, born 1965, received his Ph.D. degree in 1989. He was involved in the research of mechanics of materials and structures and now at CARS works on application of steel fibre reinforced concrete and the study and design of cable-stayed bridges.

SUMMARY

This paper presents the main experimental results of steel fibre reinforced concrete. Several practical application cases of steel fibre reinforced concrete to damaged bridge repair are introduced. It can be concluded that this new structural material has potential for being used in bridge repair.

RÉSUMÉ

L'article présente les principaux résultats expérimentaux concernant les bétons avec fibres d'acier. Plusieurs applications pratiques de tels bétons à des réparations de ponts endommagés sont présentés. Ce nouveau matériau a un potentiel d'utilisation pour la réparation des ponts.

ZUSAMMENFASSUNG

Der Beitrag stellt Forschungsergebnisse zu stahlfaserverstärktem Beton vor. Behandelt werden mehrere praktische Anwendungen in der Reparatur beschädigter Brücken. Die Möglichkeiten dieses Werkstoffs in der Brückensanierung erscheinen vielversprechend.

1. INTRODUCTION

In the past decades, steel fiber reinforced concrete has been investigated worldwide. Compared with normal concrete, steel fiber reinforced concrete has higher tensile, compressive, flexual and shear strength. Moreover, steel fiber reinforced concrete has much better ductility than normal concrete and thus its impact toughness and fracture energy rise to the extent as many times as those of normal concrete. Just because of the advantages of steel fiber reinforced concrete over normal concrete, it behaves to be one kind of much potential engineering materials to be used to special engineering such as bridge deck layment, road paving and airport runway engineering. Especially to the repair of damaged structures, steel fiber reinforced concrete behaves to be advantageous over many other engineering materials mechanically and economically.

Up till present, many existing bridges have served over 40 years. High proportion of concrete bridges, manson bridges and bridge piers have been working in the state with cracks and other kinds of damages. If these damaged structures can be suitably repaired or strengthened, they can continue to serve, and thus much finance can be saved. Otherwise, if these structures are not reasonably rehabilitated, the low safety and poor servicibility of the structures may cause a much higher loss of money and human life. In China, many highway and railway bridges at present need to be strengthened. Therefore, how to repair or reinforce these damaged bridges so as to make them work safely is a very significant research topic, which has focused much attention of research institution and administration department. With the development of the research on behavior of steel fiber reinforced concrete, steel fiber reinforced concrete has also been investigated to be applied to the repair of damaged bridges.

2. MECHANICAL BEHAVIOR

2.1 Static Strength

Static strength of steel fiber reinforced concrete may be expressed with following formulus:

$$f=f_m(1+\alpha\, l/dV_f)$$

where

f, f_m —— strength of steel fiber reinforced concrete and concrete matrix respectively

l/d —— characteristic length of steel fiber

V_f —— volumetric content of steel fiber

α —— a factor

From experiments, α is listed in Table 1.

Items	α	μ	δ
Tensile	0.72	1.03	0.14
Shear	0.55	1.01	0.10
Flexual	0.73	1.04	0.08

Table 1 Statistic value of α

Under triaxial compression, strength of steel fiber reinforced concrete is also increased.

2.2 Deformation Behavior

Figure 1 represents stress- strain curves of steel fiber reinforced concrete under uniaxial compression. The grade of concete matrix of the specimens is C35. The content of steel fiber ranges from 0. 0 to 1. 5 percent.

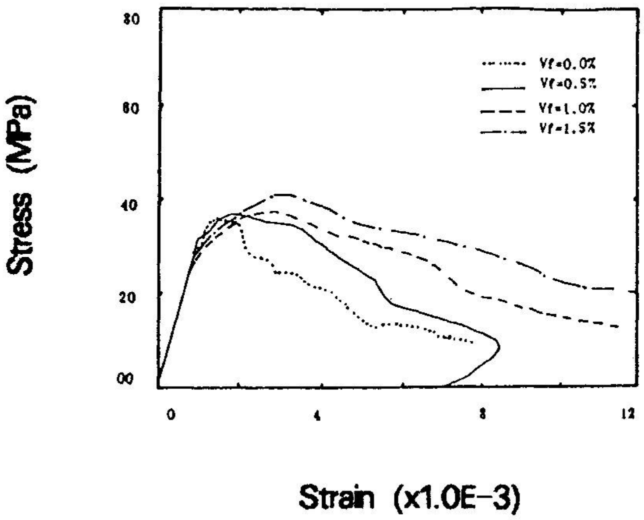


Fig.1 Stress-strain curve

From Figure 1, it can be seen that the addition of steel fiber slightly arises the compressive strength of steel fiber reinforced concrete, but post-peak cracking behavior of steel fiber reinforced concrete is highly improved with the increase of the content of steel fiber.

Therefore, the ductility of steel fiber reinforced concrete becomes much greater than that of normal concrete. The strain corresponding to the peak stress may be expressed as

$$\varepsilon_f = \varepsilon_{fm}(1+0.275l/dV_f)$$

where

ε_f, ε_{fm} —— strain corresponding to peak stress of steel fiber reinforced concrete and concrete matrix respectively

For flexual behavior of steel fiber reinforced concrete, its flexual strength and flexual failure deformation may be expressed as

$$f=f_m(1+0.509l/dV_f)$$
$$w=w_m(1+1.029l/dV_f)$$

where

f, f_m —— flexual strength of steel fiber reinforced concrete and concrete matrix respectively

w, w_m —— flexual deformation of steel fiber reinforced concrete and concrete matrix respectively

For tensile behavior, peak stress and corresponding strain can be expressed with following formulus

$$f=f_m(1+33.4V_f)$$
$$\varepsilon = \varepsilon_m(1+46.5V_f)$$

where

f, f_m —— tensile strength of steel fiber reinforced concrete and concrete matrix respectively

ε, ε_m —— tensile strain of steel fiber reinforced concrete and concrete matrix respectively

2.3 Fracture Energy and Fracture Toughness

From experiments, it can be obtained that fracture energy and fracture toughness of steel fiber reinforced concrete can be expressed as

$$G_F=G_{Fm}(1+7.788l/dV_f)$$
$$G_{IC}=G_{ICm}[1+1.997(l/dV_f)^2]$$

where

G_F, G_{Fm} —— fracture energy of steel fiber reinforced concrete and concrete matrix respectively

G_{IC}, G_{ICm} — fracture toughness of steel fiber reinforced concrete and concrete matrix respectively

Figure 2 represents load- displacement relation of steel fiber reinforced concrete under three point bending of fracure toughness test specimens.

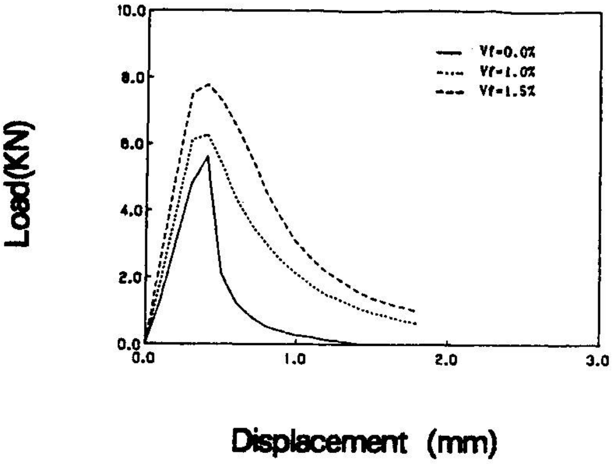


Fig. 2 Load-displacement curve

2.4 Fatigue Behavior

From experiments, fatigue behavior of steel fiber reinforced concrete is much better than that of normal concrete. Under uniaxial compressive fatigue, fatigue life of steel fiber reinforced concrete may be elongated by 20 percent of that of normal concrete. Under flexual fatigue, fatigue life of steel fiber reinforced concrete can reach 1 to 7 times of that of normal concrete. S- N relation of steel fiber reinforced concrete under flexual fatigue can be described with

$$S=A-B\log N$$
$$A=0.894+15.7V_f$$
$$B=0.051+1.5V_f$$

Based on the experimental results discussed above, it can be assumed that steel fiber reinforced concrete may be one kind of effective materials to damaged bridge repair.

3. APPLICATION TO BRIDGE REPAIR

3.1 Yanjia River Bridge

Yanjia river bridge, constructed in 1907, with the length of 92m, is a railway bridge situated near Dalian City, Liaoning Province on the railway line from Changchun to Dalian. It consists of 3 spans of steel girders. The height of bridge piers is 20.6m. The bridge is situated in the earthquake region. Because of long time service, its manson piers appeared many cracks. When trains passed the bridge, it vibrated with large amplitude. Transport administration department asked to strengthen the piers of the bridge. From 1985 to 1986, the repair project was worked out. Total amount of 650 cubic meters of steel fiber reinforced concrete and 60 tons of steel fiber were used in the project

After the repair, vibration amplitude of bridge pier No.1 is reduced to 0.29mm from previous 1.22mm, and the amplitude of pier No.2 is reduced to 0.3mm from 1.06mm.

3.2 Fengtai Crossing Bridge

Fengtai crossing bridge is a frame structure bridge with the span of 14 .9+17.5+17.5+14.9, situated at Fengtai, Beijing. During construction, serious cracks appeared on the walls. According to the engineering requirement, steel fiber reinforced concrete was selected to be applied to the bridge repair. From September to Octomber, 1990, the repair work was completed within only one month. More than 600 cubic meters of steel fiber reinforced concrete and 80 tons of steel fiber were used. The service state of this bridge after repair behaves very satisfactory.

3.3 Santaizi River Bridge

Santaizi river bridge was built in 1940's, situated on the railway line from Shenyang to Shanhaiguan. Reinforced concrete girders deteriorated very seriously. In 1987, under the condition of not stopping traffic, steel fiber reinforced concrete was used to repair the concrete girders.

4. CONCLUSION

Steel fiber reinforced concrete has good physical and mechanical behavior. Therefore, it can be efficiently applied to damaged bridge repair. Many practical applications of steel fiber reinforced concrete have also proved this conclusion.

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