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Ductility of concrete slabs reinforced with low-ductility welded wire fabric and steel fibers

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Abstract. The use of low-ductility welded wire fabric (WWF) as a main tensile reinforcement in concrete slabs compromises the ductility of concrete structures. Lower ductility in concrete structures can lead to brittle and catastrophic failure of the structures. This paper presents the experimental study carried out on eight simply supported one-way slabs to study the structural behavior of concrete slabs reinforced with low-ductility WWF and steel fibers. The different types of steel fibers used were crimped fiber, hooked-end fiber and twincone fiber. The experimental results show that the ductility behavior of the slab specimens with low-ductility reinforcement was significantly improved with the inclusion of 40kg/m^3 of twincone fiber. Distribution of cracks was prominent in the slabs with twincone fiber, which also indicates the better distribution of internal forces in these slabs. However, the slab reinforced only with low-ductility reinforcement failed catastrophically with a single minor crack and without appreciable deflection.

Keywords: concrete; ductility; fiber reinforced concrete; welded wire fabric

1. Introduction

The influence of steel fibers on the ductility and ultimate-strength capacity of concrete slabs is well known (Falkner and Teutsch 1993, Lok and Pei 1998, CIA 2003, Roesler *et al.* 2004, Khaloo and Afshari 2005, Falkner *et al.* 1995). The structural behavior of concrete slabs with low-ductilty welded wire fabric or mesh (WWF) has also been investigated by many researchers in the past (Smith and Gilbert 2003, Patrick 2005, Gilbert and Smith 2006, Gilbert and Sakka 2007, Gilbert 2009, Foster and Kilpatrick 2008); however, there is very limited published research on the combined effects of steel fibers and low-ductulity welded mesh on the structural behavior of concrete slabs. With this in view, the main focus of this paper is to study the structural behavior of concrete slabs reinforced with the low-ductility welded mesh and steel fibers. The current Australian standard (AS/NZS 4671 2001) classifies reinforcing steels into two categories in terms of its ductility: Class N and Class L. Class N stands for normal ductility steel which includes hot rolled deformed bars. Class L, on the other hand, stands for low ductility steel which includes welded wire fabric/mesh (WWF) and cold worked wires. Ductility of a material is defined as its ability to elongate plastically without fracture (Warner *et al.* 1998). The ductility of reinforcing

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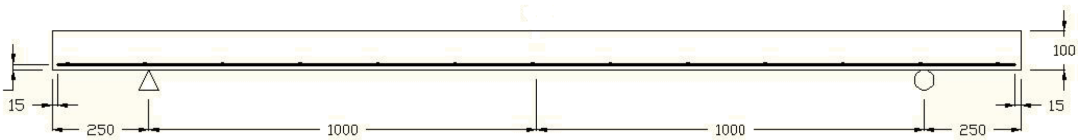
steel is usually specified in terms of the maximum elongation (ε_{su}) at peak stress and the minimum tensile strength to yield stress ratios $(f_{st}/f_{sy})_k$ (Gilbert and Sakka 2007). According to AS36009 (2009), Class L and Class N reinforcing steel should have minimum lower characteristic uniform elongation (ε_{su}) of 1.5% and 5%, respectively; and minimum tensile strength to yield ratios $(f_{st}/f_{sy})_k$ of 1.03 and 1.08, respectively. Gilbert and Smith (2006) highlighted that minimum specified value for ε_{su} for Class L steel in Australian design standard is much smaller compared to other design standards around the world (e.g., ε_{su} = 2.5% for similar class steel in Eurocode 2). The low ε_{su} for Class L steel means that it has very low ductility and it fractures in a very brittle manner. Past experimental and numerical research have concluded that the use of Class L reinforcement in suspended concrete slabs can lead to a non-ductile, brittle failure of the structure with the fracture of tensile reinforcement.

In reinforced concrete structures, structural ductility is important to guarantee that sudden and brittle failure of structures is avoided. Significant deflection that occurs in ductile structure insures sufficient prior warning of the impending failure of the structure (Kilver 2004). By using Class L mesh as the major tensile reinforcement in concrete slabs, the ductility of slabs is significantly reduced resulting in the fracture of the tensile steel at failure instead of the crushing of concrete in compression. The lack of ductility of concrete members containing Class L reinforcement is mainly due to the strain localisation. Gilbert and Smith (2006) have experimentally verified that WWF in concrete slabs has excellent bond characteristics, which facilitates strain localisation. It was found that the plastic deformation in the steel reinforcement was confined to a very short length of the reinforcing bar near the critical crack section. Consequently, there is very little rotational capacity at the critical sections and the deflection just before the fracture of the reinforced concrete section is very small. Foster and Kilpatrick (2008) have also confirmed that high degree of strain localisation occurs in high-bond, high-strength welded wire meshes particularly with small diameter wires. The recently updated Australian standard for Concrete Structures, AS3600 (2009), also accounts for the low ductility achieved with Class L reinforcement and its limited ability to distribute moments as implied by the simplified analysis. In AS3600 (2009), the strength reduction factor for slabs is reduced from $\emptyset$ = 0.8 for Class N steel to $\emptyset$ = 0.64 for Class L reinforcement to account for the lack of ductility and brittle failure mode of the structures with Class L reinforcement. WWF are, however, still widely used in residential slabs and footings mainly because it requires less manual labour to setup; has greater accuracy with respect to spacing requirements; and the splice (or lap) length of WWF is much shorter than that of Class N reinforcing bars (Patrick 2005).

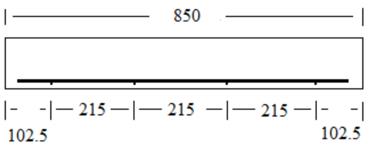
One possible method that may help to improve the ductility of a concrete slabs containing Class L reinforcement is the inclusion of steel fibers in the concrete mix. The steel fiber reinforced concrete (SFRC) has better post-cracking ductility and greater distribution of cracks in the concrete (Falkner and Teutsch 1993, Lok and Pei 1998, CIA 2003, Roesler *et al.* 2004). SFRC has the ability to redistribute the internal stresses, and thus can continue to carry the load until the ultimate failure load is reached (Khaloo and Afshari 2005). Experimental and numerical studies carried out by Roesler *et al.* (2004), Khaloo and Afshari (2005) indicated that the addition of steel fibers in concrete improves the energy absorption capacity of concrete slabs. Roesler *et al.* (2004) further argued that the fiber type (material, aspect ratio, and fiber geometry) and fiber content have significant influence on the ultimate load-carrying capacity of the concrete slabs. There are many different fiber types that are used to reinforce concrete structures, ranging from standard crimped steel fibers to stainless steel fibers with special anchorage. The properties of SFRC vary significantly with fiber characteristics such as end anchorage, and tensile strength and aspect ratio

Table 1 Experimental program

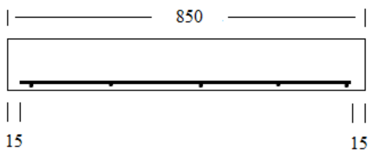
Slab	Steel reinforcement				Steel fiber
	Type	D_b (mm)	A_{st} (mm^2)	ρ (%)	
SN1	N12	12.0	452	0.67	Nil
SL2	SL82	7.6	354	0.52	Nil
SL3	SL82	7.6	354	0.52	Crimped fiber: 30 kg/m^3
SL4	SL82	7.6	354	0.52	Crimped fiber: 40 kg/m^3
SL5	SL82	7.6	354	0.52	Hooked-end fiber: 30 kg/m^3
SL6	SL82	7.6	354	0.52	Hooked-end fiber: 40 kg/m^3
SL7	SL82	7.6	354	0.52	Twincone fiber: 30 kg/m^3
SL8	SL82	7.6	354	0.52	Twincone fiber: 40 kg/m^3



(a) Longitudinal section



(b) Cross-section of slab SN1



(c) Cross-section of slab SL2 to SL8

Fig. 1 Experimental arrangements and details of the test slabs

(Falkner and Teutsch 1993).

This paper investigates the structural behavior of steel fiber reinforced concrete slabs with Class L reinforcement. Deformation controlled laboratory tests were carried out on eight one-way concrete slabs to observe the ultimate limit state behavior, with a particular focus on the effect of steel fibers on the failure mode and deformation of slabs with Class L welded wire fabric. Three types of steel fibers used in the study are: crimped fibers, hook-end fibers and twincone fibers at the dosage rate of 30 kg/m^3 and 40 kg/m^3.

2. Experimental details

2.1 Test slabs

In this study, deformation controlled tests were carried out on eight simply supported one-way concrete slabs (Table 1). All of the slabs were 2500 × 850 mm and 100mm thick (Fig. 1). Slab (SN1) consisted of Class N (N12) reinforcing steel of 12mm diameter. Rest of the slabs (SL2 to SL8) consisted of Class L reinforcement. Class L reinforcement used in this study is SL82 welded mesh with longitudinal and cross wire diameter of 7.6mm and are both spaced at 200mm centres.

Fig. 2 Experimental arrangement and instrumentation

Both N12 and SL82 reinforcing steels are of Grade 500, i.e., yielding stress (f_{sy}) of the reinforcing steel is 500 MPa.

Slab SL2 consisted of Class L reinforcement alone whereas six slab specimens (SL3 to SL8) consisted of three different types of steel fibers at dosage of 30 kg/m^3 and 40 kg/m^3 (Table 1). The three different types of steel fibers investigated in this study are crimped fiber, hooked-end fiber and twincone fiber. The reinforcement ratio (ρ) in slab SN1 is 0.67%, which is greater than other specimens with Class L reinforcement (ρ = 0.52%). SN1, hence, will have a greater moment capacity than the other slabs (SL2-SL8), however, the main purpose of testing SN1 is to compare the ductility of slabs containing normal-ductility reinforcement with the low-ductility welded mesh rather than directly comparing the ultimate moment capacities of the slabs.

2.2 Experimental setups and instrumentation

Each simply supported slab had a span of 2000mm between the supports with 250mm overhang at each support and were subjected to controlled deformation using a 300kN hydraulic jack (Fig. 1). A single-line load was applied across the full width of the slab at the mid-span (Fig. 2). The deflection at mid-span was measured using linear variable differential transducer (LVDT). All the slabs were loaded with controlled deformation. Tensile strains in the reinforcement were measured with strain gauges attached to the reinforcements at the mid-span. Strain gauges were attached to the top surface of concrete at the mid-span of the slabs to measure the compressive strains in concrete.

3. Material properties

3.1 Concrete mix design

Concrete for casting the slabs was supplied by Holcim Australia. Super plasticizer (dosage rate of 600ml per 100kg of cementitious material) and steel fibers were added into the concrete truck and mixed with the concrete at the site. The mix design of concrete for the slabs with twincone fibers (SL7 and SL8) were slightly different than for the other slabs (Table 2) to prevent the balling-effect of the fibers.

Table 2 Concrete mix design

Description	Mix design for SN1, SL2 to SL6	Mix design for SL7 and SL8
Concrete	1.0 m^3	1.0 m^3
Course sand	570 kg	570 kg
10mm aggregate	360 kg	320 kg
20mm aggregate	730 kg	740 kg
Fine sand	360 kg	400 kg
Fly ash	98 kg	90 kg
Super plasticizer	1.9 L	1.9 L
Cement	220 kg	218 kg
Water	90 L	81 L

Table 3 Compressive and flexural tensile strength of concrete mixes

Fiber type/content	f'_c (MPa)	f'_{cf} (MPa)
Plain concrete	36.3	3.0
With crimped fiber (30 kg/m^3)	34.3	3.1
With crimped fiber (40 kg/m^3)	32.1	4.0
With hooked-end fiber (30 kg/m^3)	37.7	3.3
With hooked-end fiber (40 kg/m^3)	38.8	3.4
With Twincone fiber (30 kg/m^3)	38.6	4.0
With Twincone fiber (40 kg/m^3)	37.2	4.6

Concrete compressive strength tests and flexural strength tests were conducted in accordance to AS1012.9 (1999) and AS1012.11 (2000), respectively and the results are shown in Table 3 for different mixes at the time of testing. The compressive strength (f'_c) was determined from the standard 150mm diameter cylinders and the flexural tensile strength (f'_{cf}) was obtained from the standard 100x100x500mm rectangular beams. It was observed that the addition of steel fibers had little effect on the compressive strength of the concrete; however, fiber type and quantity had a significant effect on the flexural tensile strength of concrete. Twincone fiber, at 40 kg/m^3 dosage, produced the highest flexural tensile strength.

3.2 Reinforcing steels

As mentioned earlier, two different types of reinforcing steels were used in the concrete slabs. The slab SN1 consists of normal ductility N12 (f_{sy} = 500 MPa) deformed bars and slabs SL2 to SL8 are reinforced with low-ductility SL82 welded wire fabric (f_{sy} = 500 MPa). Generic tensile stress-strain behavior of N12 and SL82 reinforcing steel are shown in Fig. 3 (CIA 2003).

3.3 Fiber types

Three different types of fibers (crimped, hooked-end and twincone fibers) were investigated in this study. Dosage of 30 kg/m^3 and 40 kg/m^3 of fibers were used in the slabs as shown in Table 1. Crimped fibers have a wave shape to improve bond between the fiber and the concrete. Crimped fibers are generally used to control plastic shrinkage cracking and to improve tensile properties of

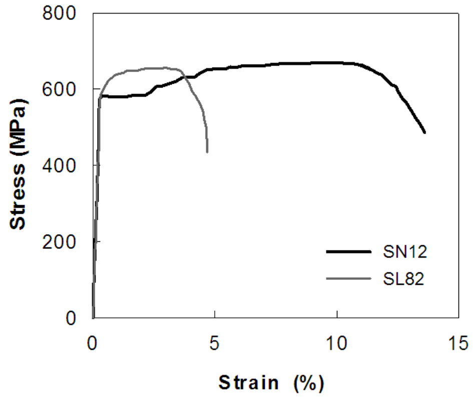


Fig. 3 Stress-strain curve for N12 (Class N) and SL82 WWF (Class L) reinforcing steel (CIA 2003)

(a) Crimped fiber (b) Hooked-end fiber (c) Twincone fiber

Fig. 4 Types of fibers used in the study

Table 4 Steel fiber types used in the study and their properties

Properties/Type	Crimped	Hooked-end	Twincone
Length	50 mm	60 mm	54 mm
Fiber diameter	1.15 mm	0.90 mm	1 mm
Head diameter	-	-	2 mm
Wave height	1.1 mm	-	-
Tensile strength	800 – 1000 MPa	1100 MPa	1100 MPa
Aspect ratio	42	67	54

concrete mix. Hooked-end fibers, on the other hand, have a greater capacity to transfer load over the critical cracked section, due to the shape of fibers. Twincone fibers are straight fibers with punched conical heads at both ends. These cones allow the fibers to be completely anchored in the concrete matrix and prevent the pull out. Table 4 and Fig. 4 show the dimensions and shape of the fibers.

4. Slab test results and discussion

4.1 Mode of failure

The load at which the tensile cracking on the soffit of the slab started was recorded by visual inspection and the yielding point of the longitudinal reinforcement was noted from the tensile strain readings of the strain gauges attached to the mid-span reinforcement. All the cracks were visually inspected and marked during the test.

On the soffit of the slab SN1 with Class N reinforcement, one main crack was observed at the midspan of the slab with parallel minor cracks on either side of the main crack at approximately 150mm increments (Fig. 5). With increase in the load, the slab sustained a large deflection and ultimately failed with the crushing of the concrete in compression, which demonstrates an excellent ductility of the slab with Class N reinforcement. The key point to note here is that the tensile steel in slab SN1 yielded but did not fracture. The ability of a concrete structure member to distribute an applied load over a critical section is directly related to crack distributions in the member. A large number of parallel cracks in slab SN1 indicate that the slab was able to distribute the applied load over a large area, which also demonstrates its ductile behavior.

On the other hand, only a single crack spanning over the entire width of the slab was observed on the soffit of slab SL2 with Class L reinforcement (Fig. 5). This crack only appeared minor compared to those observed in SN1. The failure of the slab was brittle and catastrophic with the fracture of the tensile reinforcements. As also pointed out by Gilbert and Smith (2006), excellent bond between deformed welded wire fabric and concrete caused strain localization; this led to the brittle failure of Class L reinforced slab (SL2).

For slab SL3 and SL4, with 30kg/m^3 and 40kg/m^3 of crimped fiber, a prominent crack was observed along the midspan of each slab. A very fine crack, approximately 100mm from the main crack, was also observed for SL3 and SL4. It was found out that addition of crimped fibers made very little difference to crack distribution and failure pattern of the slabs.

The effect of varying dosages of hooked-end fibers in the slab containing Class L reinforcement was seen from slabs SL5 and SL6. The amount of cracking in each specimen is significantly greater than those observed in slab SL2 to SL4. Evidently, the hooked-end fibers improved the structural performance of the slab containing Class L reinforcement. It can be seen that the main crack just prior to failure is much well defined compared to previous specimens. Also, along the side of this slab numerous cracks branched off the main crack. Even more extensive cracking on the soffit of the specimen was observed in SL6. A key observation for SL6 is that fine cracks (as in SN1), approximately at the increments of 150mm, extended along the entire width of the specimen on either side of the main crack. It was concluded from the observation of the crack patterns in SL5 and SL6 that there was more distribution of the internal

(a) SN1 (b) SL2

Fig. 5 Cracking on soffit of the slabs

(a) SL7 (b) SL8

Fig. 6 Cracking on soffit of the slabs

forces than what had occurred in SL2. The increase in the amount of distribution of internal forces also explains the increase in the ductility attributed to the hooked-end fibers. However, the final failure of slabs SL5 and SL6 was caused by the fracture of tensile reinforcement before the concrete crushed in compression.

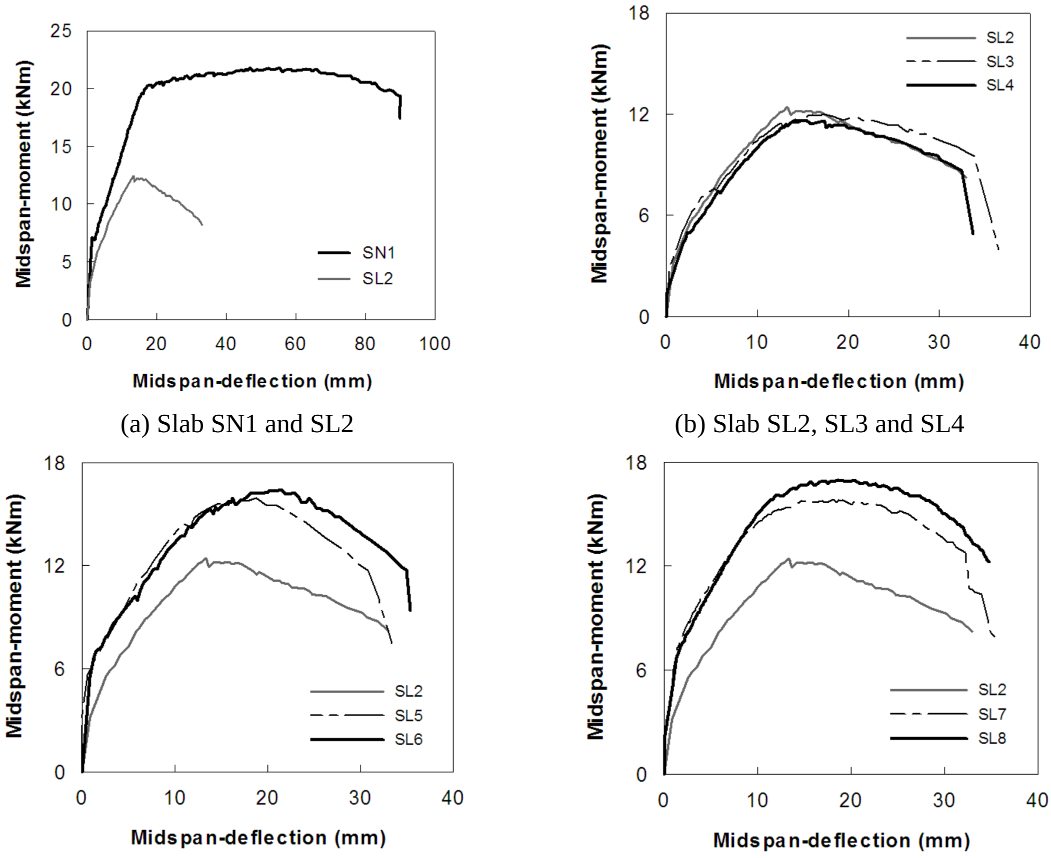
Fig. 6 shows the cracking pattern just prior to failure of SL7 and SL8 slabs with twincone fibers at dosage of 30kg/m^3 and 40kg/m^3 along with SL82 mesh, respectively. In comparison to all other fiber types, the two specimens containing twincone fibers had the crack pattern that was most similar to SN1. The main crack was clearly defined and multiple cracks branching off the main crack were observed in SL7. Multiple cracks could form because of the greater amount of internal force distribution achieved with the use of twincone fibers.

SL8, containing 40kg/m^3 of the twincone fibers, produced the most distributed crack pattern of all the slabs containing Class L reinforcement. The conical head of the twincone steel fibers allow them to be fully anchored into the concrete matrix. Furthermore, it results in distribution of cracks along the slab and minimizes the strain localization. The maximum compressive strains in concrete for SL7 and SL8 both exceeded 0.003, which indicated that the concrete had started to crush; however, as the displacement increased, the collapse of the slabs occurred with the fracture of the tensile reinforcement.

4.2 Ultimate strength and ductility behavior

4.2.1 Moment-deflection characteristics

The Maximum moment versus the midspan-deflection curves for all the slabs are shown in Fig. 7. Fig. 7(a) shows the midspan-moment versus the midspan-deflection curves for SN1 and SL2. Both of these slabs contained no steel fibers in the concrete mix. As mentioned earlier, the ultimate moment capacities of SN1 and SL2 cannot be directly compared, because the reinforcement ratio for SN1 (ρ =0.67%) is larger than that of SL2 (ρ = 0.52%). However, the comparison that can be made between the two specimens is the shapes of each curve and their failure patterns. In both slabs, the moment-deflection appears to be linear until the point where the main tensile reinforcement began to yield. Clear large yield plateau can be observed in the slab SN1. This prominent yield plateau in the moment-deflection curve for SN1 provides a prior warning of the imminent failure. On the contrary, a very small yield load plateau (and hence, the little ductility) was observed in slab SL2. As soon as the maximum moment capacity was attained, failure occurred catastrophically without any warning. The mid-span deflections where the yielding of



(a) Slab SN1 and SL2

(b) Slab SL2, SL3 and SL4

(c) Slab SL2, SL5 and SL6

(d) Slab SL2, SL7 and SL8

Fig. 7 Mid-span moment vs. mid-span deflection

reinforcement occurred for SN1 and SL2 were 13.6mm and 9.9mm, respectively. The corresponding deflections of SN1 and SL2 at ultimate moments were 55.2mm and 13.4mm, respectively (Table 5).

Fig. 7(b) demonstrates the effects of adding different dosages of crimped fibers to the concrete slab containing SL82 mesh. It can be seen that addition of crimped fibers in the slabs SL3 and SL4 have very little effect on the shape of the moment-deflection relationship and the ultimate moment capacity of the slabs. The strain values obtained from the reinforcement strain gauge showed that yielding of reinforcement occurred at the mid-span deflection of 11.2mm and 10.8mm for SL3 and SL4 slabs, respectively. The applied moments continue to sharply increase and soon reach the ultimate moment capacities of 11.9kNm and 11.6kNm at mid-span deflections of 17.3mm and 15.3mm for SL3 and SL4, respectively. Soon after reaching the ultimate capacities, the main tensile reinforcement fractured in both of the cases resulting in a catastrophic collapse.

Fig. 7(c) illustrates the effects of adding 30 kg/m^3 and 40 kg/m^3 of hooked-end fibers to the concrete slab with SL82 mesh. The results showed slight improvement in ductility of the slabs with hooked-end fibers compared to the Class L reinforcement alone. Yielding of reinforcement for SL5 and SL6 occurred at 13.5mm and 11.8mm, respectively. A mild plateau was observed

Table 5 Peak moments, deflections and ductility ratio for slabs SN1 and SL2 to SL8

Specimen	Peak moment (M_{max}) kN-m	Yield deflection (Δ_y) mm	Deflection at peak load (Δ_y) mm	W_y kN-mm	W_u kN-mm	Ductility ratio (μ_d)
SN1	21.8	13.6	55.2	293	1972	6.7
SL2	12.4	9.9	13.4	130	199	1.5
SL3	11.9	11.2	17.3	148	263	1.8
SL4	11.6	10.8	15.3	125	221	1.7
SL5	15.9	13.5	18.8	299	457	1.5
SL6	16.4	11.8	21.5	219	513	2.3
SL7	15.8	11.1	20.5	225	509	2.3
SL8	16.9	9.8	20.3	195	522	2.7

when the applied moment was sustained with the increase in mid-span deflection. Ultimate moment capacities of 15.9 kNm and 16.4 kNm at mid-span deflections of 18.8mm and 21.5mm were achieved in SL5 and SL6, respectively. The ultimate moment capacity was also increased for both of the specimens compared to SL2. This is attributable to the better anchorage of hooked-end fibers within the concrete section.

The final two slabs that were subjected to testing were SL7 and SL8, which contained twincone steel fibers with 30 kg/m^3 and 40kg/m^3 dosage respectively. Fig. 7(d) shows the effects of twincone fiber on the behavior of slabs containing Class L reinforcement. The yielding of the reinforcement occurred at 11.1 mm and 9.8 mm mid-span deflection for SL7 and SL8, respectively. The moment-deflection relationship illustrates that a yield plateau is better defined for the slabs with twincone fibers compared to slabs SL5 and SL6. The conical full anchorage heads of the twincone fiber resulted in the better bond of fibers with the concrete. This could have decreased the effects of strain localisation in each specimen and increased the amount of internal force distribution across a larger critical section, resulting in a greater ductility in both SL7 and SL8. The ultimate moment capacities of SL7 and SL8 were 15.8 kNm and 16.9 kNm with corresponding mid-span deflections of 20.5mm and 20.3mm, respectively.

4.2.2 Ductility behavior

Ductility of a structural member can be expressed either in terms of deflection ratio (ratio of deflection at peak load to the deflection at the yielding load) or in terms of absorbed energy ratio (ratio of total work done by the load till peak load to the work done till the yielding point) (Sakka 2009). In this study, ductility (μ_w) is expressed as absorbed energy ratio as defined by Eq. (1). Energy absorbed by the specimen is represented as the total work done by the load which can be calculated as the area under the load-deflection curve as explained in Fig. 8 and Eq. (1).

$$\mu_w = W_u / W_y \tag{1}$$

where,

W_y : Elastic energy absorbed between zero deflection and deflection at the yielding point (Δ_y)

W_u : Total energy absorbed between zero deflection and deflection at the peak load (Δ_u)

A_0 : Area under the load-deflection curve in the elastic range between deflections 0 to Δ_y

A_1 : Area under load-deflection curve in the plastic range between deflections Δ_y to Δ_u

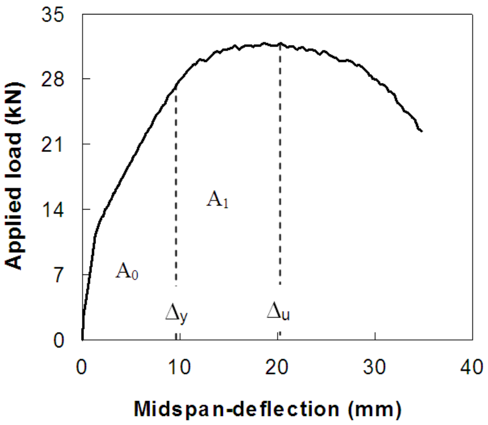


Fig. 8 Typical load-deflection curve for steel fiber reinforced slab with Class L reinforcing steel

Table 5 indicates peak moments, midspan-deflections and corresponding ductility ratio for all the slabs. Slab SN1 with normal ductility N12 reinforcing bars shows excellent ductility (μ_w = 6.7) whereas slab SL2 with low ductility SL82 WWF exhibits a very poor ductility (μ_w = 1.5). Addition of mill-cut fibers (30 kg/m^3 and 40 kg/m^3) and hooked-end fibers at dosage of 30kg/m^3 did not improve the ductility of the slab. Ductility of slab SL8, with Twincone fiber of 40 kg/m^3, was significantly improved (μ_w = 2.7) compared to slab SL2 with WWF alone. AS3600 (2009) regards the structural elements with ductility ratio less than 2 as brittle and is not desirable; whereas, the structural elements, with ductility ratio greater than 5, behave in very ductile manner and are suitable for high level of loads for example earthquake loadings. Structural elements with ductility factor between 2 to 5 can be used for general design purpose; however, moment-redistribution is not allowed in the design of such structures. This again highlights that slabs with WWF alone are mostly likely to fail in brittle manner. Addition of steel fibers improves the ductility of the slabs with Class L reinforcement; however, ductility gain is significantly influenced by the type of steel fibers used and the quantity of the fibers. It was found that slabs with twincone fibers at dosage greater than 30 kg/m^3 and hooked-end fiber at the dosage of 40 kg/m^3 had acceptable level of ductility.

5. Conclusions

This study investigated experimentally the structural performance of one-way simply supported slabs containing low-ductility welded mesh reinforcement and different steel fibers at varying dosage. It was observed that the concrete slab with low-ductility welded mesh failed in a catastrophic manner through the fracture of the tensile reinforcement without any appreciable deflection warning. The ductility ratio obtained for the slab with low-ductility welded mesh was only 1.5. AS3600 (2009) specifies that concrete members with the ductility ratio less than 2 are brittle and should be avoided.

It was demonstrated that the addition of steel fibers in the concrete slabs with low-ductility mesh improved its ultimate flexural strength, energy absorption capacity and ductility. However, the type of fiber and fiber content had significant influence on the structural performance of the slabs. Inclusion of 40kg/m^3 of twincone fiber enhanced the flexural capacity and ductility of the slabs by 36% and 80%, respectively. Ductility of 2.3 and 2.7 could be achieved with twincone fibers at dosage of 30kg/m^3 and 40kg/m^3, respectively. This level of ductility is acceptable for design of normal concrete structures according to AS3600 (2009); however, the code does not allow moment re-distribution in the design of such structures. Twincone fibers were found to be more effective compared to hooked-end and mill-cut fibers in improving energy absorption capacity and ductility of the slabs. Ductility of 2.3 was achieved with hooked-end fiber at 40kg/m^3; however, mill-cut fiber and lower dosage of hooked-end fiber had very little effect on the structural behavior of the slab.

This paper looks into a new frontier of using welded wire fabric along with steel fibers for construction of concrete slabs. Combining welded wire fabric with steel fibers brings about a synergy of the convenience (what the welded wire fabric has to offer) and ductility (achieved through steel fibers).

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