

Results analysis and discussions health essay

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CHAPTER 4

4. 1 Introduction

This chapter consists of three parts: Results and observations for preliminary tests on aggregates and macro synthetic fibres Results analysis and dicussions for fresh concrete Results analysis and dicussions for hardened concrete.

4. 2 Results and Observations for Preliminary Tests on Aggregates and Macro synthetic fibres

4. 2. 1 Preliminary Tests on Aggregates

4. 2. 1. 1 Relative Density and Water Absorption

The results for the relative density and water absorption tests on fine and coarse aggregates are given in Table 4. 1.

Table 4. 1: Relative Density and Water Absorption for Aggregates

Property

Fine Aggregate

Coarse Aggregate

0-4mm

6-10mm

14-20mm

Relative density on OD basis 2. 782. 692. 66 Relative density on SSD basis 2. 882. 762. 72 Apparent relative density 2. 982. 872. 82 Water absorption (% of dry mass) 2. 402. 302. 10

Observations

From Table 4. 1, it can be observed that the relative densities of both fine and coarse aggregates were found to lie in the range 2. 6-3. 0 (Neville, 1995). The water absorption of fine aggregates was found to be slightly more than those of the coarse aggregates.

4. 2. 1. 2 Grading

The sieve analysis test results carried out on aggregates are illustrated in Figure 4. 2. Table 4. 2 displays the sieve analysis results for fine aggregate along the overall limit from BS 882: 1992.

BS Sieve Size (mm)

Wt of sieve (g)

Wt of sieve + sample (g)

Wt of sample (g)

% Retained

Cummulative

% Passing

Overall Limits

6. 700531. 55531. 730. 180. 0199. 99

-

4. 760510. 80510. 9320. 131. 2199. 97

-
 2. 360465. 79733. 50267. 7116. 3582. 6260-1001. 180423. 42874. 32450.
 9027. 2155. 4130-1000. 600396. 52652. 10255. 5815. 4239. 9915-1000.
 425443. 02536. 7293. 705. 6534. 335-700. 300376. 86462. 6985. 835. 1829.
 15

-
 0. 150295. 91432. 78136. 878. 2620. 890-200. 075421. 46574. 06152. 609.
 2111. 69

-
 Retainer409. 23602. 89193. 6611. 690. 00

Total

1657. 1699. 99

Table 4. 2: Sieve Analysis of Fine Aggregate (0-4 mm)

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Figure 4. 1: Grading Limits for Fine Aggregate

Source: BS 882: 1992

Figure 4. 2: Grading curves for Fine and Coarse Aggregates

Observations

As it can be seen from the grading curves in Figure 4. 2, the fine aggregates were uniformly graded and the grading for fine aggregates complied with the overall limit stated in BS 882: 1992 as shown in Table 4. 2. The percentage passing the 600 μm sieve for the fine aggregates was read from the graph

and found to be 40. 0. The particle size distribution of coarse aggregates (6-10 mm and 14-20 mm) gave more or less similar grading curves below the 10 mm sieve.

4. 2. 2 Preliminary Test on Macro synthetic fibres

4. 2. 2. 1 Water Absorption

The results obtained from the water absorption test carried out on both macro synthetic fibres: Strux 90/40 and BarChip are displayed in Table 4. 3.

Table 4. 3: Water Absorption for Macro synthetic fibres

Property

Macro synthetic fibre

Strux 90/40

BarChip Macro

Water absorption (% by dry mass)0. 080. 04

Observations

From Table 4. 3, it can be seen that the water absorption for both macro synthetic fibres was extremely low (almost zero) such that it can be considered to be negligible. This results satisfies to what have been said about the water absorption abilities of macro synthetic fibres in the literature review and this shows that the polyolefin structure of the fibre makes it incapable of absorbing or holding water particles.

4. 3 Results Analysis and Discussion for Fresh Concrete

4. 3. 1 Workability

The workability test results are presented in Table 4. 4 and interpreted in Figure 4. 3.

Table 4. 4: Slump (mm) for each pair of mixes

Mix

Slump (mm)

0 kg/m³ fibre

2. 0 kg/m³ fibre

2. 5 kg/m³ fibre

3. 0 kg/m³ fibre

AMS1110654515

% decrease

-

40. 9

59. 1

86. 4

BMS2110705025

% decrease

-

36.4

54.5

77.3

Figure 4. 3: Effect of Macro synthetic fibres on Workability

Observations and Discussions

Figure 4. 3 indicates clearly that an increase in fibre content strongly affected workability. The variation from fibre content of 2. 0 kg/m³ to 3. 0 kg/m³ for MS1 decreased workability by 40. 9% to 86. 4% respectively compared to the control mix while for MS2, workability was decreased by 36. 4% to 77. 3% respectively. The mixes obtained at fibre content of 3. 0 kg/m³ for both MS1 and MS2 were found to be harsh and highly cohesive, thus having very low workability. It was also observed that MS1 had lower slump values than MS2 at all fibre dosages, thus lower workability. Macro synthetic fibres are known to consume cement paste by their surface areas (Grace Construction Products, 2006). Hence as fibre content increases, the surface areas of fibres increases in the mix causing greater consumption of cement paste. Also, the amount of fibre particles interlocking and entangling around the aggregate particles increased leading to an augmentation in particle interference and friction between the aggregates and fibres, thereby lowering workability. Furthermore as fibre content increases, the mixture become stiff and is less likely to deform. The reason why MS1 showed a greater decrease in workability than MS2 at all fibre dosages can be due to the differences in the surface texture of the fibres included in the pair of

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mixes. The fibres present in MS1 have flat surfaces whereas those in MS2 have continuously embossed surfaces. Fibres having flat surfaces provide a greater surface area to volume ratio to coat much more cement paste than those having continuously embossed surfaces leading to a greater decrease in workability.

4. 3. 2 Plastic Density

The results for the plastic density are given in Table 4. 5 and illustrated in Figure 4. 4.

Table 4. 5: Plastic Density (kg/m³) for each pair of mixes

Mix

Plastic Density (kg/m³)

0 kg/m³ fibre

2. 0 kg/m³ fibre

2. 5 kg/m³ fibre

3. 0 kg/m³ fibre

AMS12490249024802470

% decrease

-

0

0. 40

0. 80

BMS22490248024702460

% decrease

-

0.40

0.80

1.20

Figure 4. 4: Effect of Macro synthetic fibres on Plastic Density

Observations and Discussions

As seen in Figure 4. 4, there was a slight decrease in plastic density with increasing fibre content for both MS1 and MS2. Compared to the control mix, a net decrease of 0.80% was obtained for MS1 while 1.20% for MS2.

Moreover, MS2 showed a slightly greater decrease than MS1 at all fibre dosages. Hence it can be found that our observations matched that of Buratti et al. (2011), that is different types of macro synthetic fibres did not influence much the plastic density of the FRC. Neville and Brooks (1997) states that plastic density of concrete is influenced by the presence of voids. The greater the voids in the concrete, the less will be its plastic density.

Hence the addition of macro synthetic fibres in the mix may have caused an increase in air voids in the concrete thereby lowering the density of the fresh concrete. In fact, the dispersion of the fibres in different orientations in the fresh concrete may have caused air voids to be entrapped below or in between the fibres. With an increase in fibre content, there is a greater fibre dispersion in any direction in the mix leading to an increase in volume of entrapped air voids in the concrete. Since the volume of the test container was kept constant for all mixes, there was a decrease in the weight of the

fresh concrete due to an increase in air voids, which may account for the decrease in plastic density. Also, the density differences in the concrete mix can be another reason for this decreasing trend in plastic density for both pair of mixes. Macro synthetic fibres float on water; this shows that they are lighter than water and thus have lower density than water and constituent materials in the concrete. For an equal mass of the fibres and constituent materials of the concrete, the fibres will occupy a larger volume than the constituent materials of the concrete in a given container. Hence the an increase in fibre content will result in a larger volume occupied by the fibres leading to a decrease in plastic density of concrete. The fact that MS2 showed a slightly greater decrease than MS1 at all fibre dosages can be due to the differences in the surface texture of the fibres. The fibres having continuously embossed surfaces in MS2 caused greater amount of air voids to be entrapped below or in them than those having flat shapes in MS1.

4. 4 Results and Discussion for Hardened Concrete

4. 4. 1 Compressive Strength

The variation of compressive strength with different fibre content at an age of 7 and 28 days for each pair of mixes is shown in Table 4. 6 and represented in Figure 4. 5 and 4. 6 respectively. The raw data is given in Appendix 3. Table 4. 7 demonstrates the percentage strength increase in compressive strength of each pair of mixes with respect to the control mix (0 kg/m³ fibre) at an age of 7 and 28 days.

Table 4. 6: Compressive Strength (N/mm²) for each pair of mixes**at an age of 7 and 28 days****Mix****Age****(Days)****Compressive Strength (N/mm²)****0 kg/m³ fibre****2. 0 kg/m³ fibre****2. 5 kg/m³ fibre****3. 0 kg/m³ fibre**

AMS1720. 7523. 1023. 4321. 292830. 3334. 2434. 5132. 07BMS2720. 7522.

6521. 8720. 662830. 3332. 6033. 0630. 43

Table 4. 7: Percentage strength increase (%) in compressive strength of each pair of mixes w. r. t control mix at an age of 7 and 28 days

Mix

Age

(Days)

% Strength increase w. r. t control mix

0 kg/m³ fibre

2. 0 kg/m³ fibre

2. 5 kg/m³ fibre

3. 0 kg/m³ fibre

AMS17

-

11. 3312. 922. 6028

-

12. 8913. 785. 74BMS27

-

9. 165. 40-0. 4328

-

7. 489. 000. 33

Figure 4. 5: Variation of 7-day Compressive Strength with different fibre content

Figure 4. 6: Variation of 28-day Compressive Strength with different fibre content

Figure 4. 7: Comparison of Compressive Strength at 7 and 28 days

Observations and Discussions

Figure 4. 5 and 4. 6 clearly shows that as fibre content increased from 2. 0 kg/m³ to 2. 5 kg/m³, the 7-day and 28-day compressive strengths of both MS1 and MS2 increased up to a peak value respectively until they dropped unexpectedly as fibre content increased to 3. 0 kg/m³. At 7 days, the highest increase in compressive strength of MS1 recorded was 12. 92% compared to the control mix while that of MS2 was 5. 40%. At 28 days, the same trend was observed for both MS1 and MS2. With respect to the control mix, the 28-day compressive strength of MS1 increased by 12. 89%, 13. 78% and 5. 74% at fibre contents of 2. 0 kg/m³, 2. 5 kg/m³ and 3. 0 kg/m³ respectively. As for MS2, the 28-day compressive strength increased by 7. 48%, 9. 00% and 0. 33% respectively. Previous researchers observed an increasing trend in compressive strength for higher fibre contents. Our research on the other hand showed that higher fibre content affected strength considerably. From Figure 4. 7, it can also be found that MS2 had a lower 7-day and 28-day compressive strength values than MS1 at all fibre dosages. This increment in compressive strength can be explained by the work mechanism of the fibres in the concrete matrix. When a load is applied to concrete, there are a number of cracks which are developed and eventually propagate throughout the concrete until failure occurs. The compressive strength of MSFRC

increases as the fibres hold the cracks together and restrain the rapid propagation of cracks. Hence MSFRC can withstand more load until the fibres are no longer able to hold the cracks and failure ultimately occurs. With an increase in fibre content, the interception of cracks at a section by the fibres increases leading to an increase in strength. Another explanation for this increase in strength may be that the inclusion of macro synthetic fibres in the mix causes the formation a fibre-matrix bond in the concrete, that is the bond between the cement paste and the fibre. There is enough cement paste so that bonding of the fibres is easily formed. With an increase in fibre content, the interfacial bonding of the fibres with the cement paste increases leading to an increase in the stress when the MSFRC is subjected to loads. The reason for the downward trend in sample with fibre content of 3.0 kg/m³ for both MS1 and MS2 can probably be due to the fact that as the fibre dosage is increased, the surface area of fibres in the mix increases and the cement paste adheres to the fibres such that there is less reactive paste available for hydration reaction. Secondly, it is because of bonding issues. Some fibres tend to orient themselves vertically and horizontally thus affecting the bond strength. Therefore to enhance the distribution of fibres in a mix, it is recommended to use superplasticizers which will provide better strength. The reason why the compressive strength of MS2 was lower than that of MS1 at all time as fibre content was increased may be due to the lower elastic modulus of the fibre included in MS2 compared to that present in MS1. Upon application of load, cracks will tend to form in the concrete before the fibre can develop a resisting stress, that is to transfer stresses across the cracks thus preventing crack propagations. Hence the fibres in MS2 contribute lesser to the compressive strength than those in MS1.

Secondly, this difference in strength can be due to the shape of fibre. The flat-shaped fibres found in MS1 provide a greater surface area to volume ratio for effective bonding with the cement paste than the continuously embossed-shaped fibres present in MS2. The mechanical bond formed with the cement matrix is lower in MS2 than in MS1. Hence more force is required to cause ultimate failure of MS1 specimens than those of MS2. Thirdly, the weight difference of the fibres can explain for this difference in strength. The fibres in MS1 have lower weight than those in MS2. Therefore for a given dosage rate, the fibre count per unit volume of the fibres in MS1 is much greater than that of the fibres in MS2, thus providing better post-crack performance since there are more fibres available to intercept a micro crack and preventing it from propagating. All cube failures were non-explosive types. However it was noted that MSFRC cubes did not have the ' brittle' failure as that of the control cubes. At failure, MSFRC cubes did not burst as the macro synthetic fibres held onto broken pieces. Upon removal of the applied load, the broken pieces were seen to take their original places. It was difficult to pull off the edges of the FRC cubes (which is not the case for the normal concrete cube). This can confirm the ' ductile' behaviour of MSFRCs as stated by MacDonald FACI et al. (2009).

4. 4. 2 Flexural Strength

Flexural strength results for each pair of mixes are tabulated in Table 4. 8 and are illustrated in Figure 4. 8.

Table 4. 8: Results for Flexural Strength for each pair of mixes**Mix****Flexural strength (N/mm²)****0 kg/m³ fibre****2. 0 kg/m³ fibre****2. 5 kg/m³ fibre****3. 0 kg/m³ fibre**

AMS16. 286. 486. 956. 70

% increase

-

3. 18**10. 67****6. 69**

BMS26. 286. 366. 666. 44

% increase

-

1. 27

6. 05

2. 55

Figure 4. 8: Effect of Macro synthetic fibres on Flexural Strength

Observations & Discussions

With flexural strength, almost the same pattern was observed as for compressive strength for both MS1 and MS2 as shown in Figure 4. 8. The addition of macro synthetic fibres increased the flexural strength of both MS1 and MS2 until it decreased suddenly at higher fibre dosage. The highest increase in flexural strength obtained for MS1 compared to the control mix was 10. 67% and that for MS2 was found to be 6. 05%. It was also found that the flexural strength of MS1 was higher than that of MS2 at fibre dosages. Similar explanation as that for the increase in compressive strength holds here. The increase in flexural strength is due to the fact that macro synthetic fibres act as crack arrestors in the concrete matrix preventing the propagation of micro cracks. Another plausible explanation is that the interfacial bonding of the fibres with the cement paste increases with an increase in fibre content leading to an enhancement in flexural strength. The sudden drop in strength at fibre content of 3. 0 kg/m³ for MSFRCs may again be due to the increase in surface area of fibres in the mix. Hence cement paste adheres to the fibres such that there is less reactive paste for reaction. Also, the bond strength is greatly affected due to

the fact that some fibres orient themselves in a vertical and horizontal direction. To obtain better flexural strength, it is advised to use superplasticizers to enhance the distribution of fibres in a mix. The explanation for the difference in flexural strength between MS1 and MS2 may be due to the inferior elastic modulus of the fibre included in MS2 to that in MS1 such that the fibres in MS2 are unable to prevent crack propagation at the stress applied to the concrete. As well, the continuously embossed-shaped fibres present in MS2 provide lower surface area to volume ratio for effective bonding with the cement paste than the flat-shaped fibres in MS1 resulting in a poorer bond and hence a decrease in flexural strength. Furthermore the low weight of the fibres in MS2 compared to that of the fibres present in MS1 leads to lower fibre count per unit volume for a given dosage rate resulting in lower post-crack performance. Hence flexural strength is lowered. MSFRC specimens did not have the brittle failure as the control specimen (the control specimen showed a typical crack propagation pattern such that the beam broke into two parts and fell apart). Instead, it was found that the fibres had the ability to hold the specimens from falling apart at the position of the crack though the concrete had failed. This showed that the MSFRC is more ductile than brittle and possess post-cracking energy absorption capacity.

4. 4. 3 Tensile Splitting Strength

Test results for tensile splitting strength for each pair of mixes are displayed in Table 4. 9 and illustrated in Figure 4. 9.

Table 4. 9: Results for Tensile Splitting Strength for each pair of mixes**Mix****Tensile splitting strength (N/mm²)****0 kg/m³ fibre****2. 0 kg/m³ fibre****2. 5 kg/m³ fibre****3. 0 kg/m³ fibre**

AMS13. 493. 653. 824. 03

% increase

-

4. 58**9. 46****15. 47**

BMS23. 493. 553. 893. 98

% increase

-

1. 72

11. 46

14. 04

Figure 4. 9: Effect of Macro synthetic fibres on Tensile Splitting Strength

Observations & Discussions

From Figure 4. 9, there was a general increase in tensile splitting strength as fibre content was increased, except that the strength of MS1 was surprisingly lower than that of MS2 at fibre content of 2. 5 kg/m³. With an increase in fibre content, the tensile splitting strength increased by 4. 58%, 9. 46%, 15. 47% respectively compared to the control mix for MS1 while for MS2, it increased by 1. 72%, 11. 46%, 14. 04% respectively. The increase in tensile splitting strength compared to the control mix is due to the bridging mechanism of macro synthetic fibres which prohibits crack propagation upon application of load. The lower tensile splitting strength of MS1 than that of MS2 at fibre content 2. 5 kg/m³ may have resulted due to poor compaction being achieved. Also, it was noted that at failure, the control specimen broke into half in a brittle manner whereas MSFRC specimens did not separate even if cracks were formed. The fibres were seen to hold tightly the two pieces at the cracked sections of the FRC specimens. This therefore demonstrate the post-cracking energy absorption capacity of the macro synthetic fibres and confirms the statement of Hasan et al. (2011, p. 20).

4. 4. 4 Hardened Density

The variation of hardened density with respect to time for each pair of mixes is displayed in Table 4. 10 and illustrated in Figure 4. 10 and 4. 11 respectively. Table 4. 11 gives the percentage decrease in hardened density of each pair of mixes with respect to the control mix (0 kg/m³ fibre) at an age of 7 and 28 days.

Table 4. 10: Hardened Density (kg/m³) for each pair of mixes

at an age of 7 and 28 days

Mix

Age

(Days)

Hardened Density (kg/m³)

0 kg/m³ fibre

2. 0 kg/m³ fibre

2. 5 kg/m³ fibre

3. 0 kg/m³ fibre

AMS172427241824262426282475244324432442BMS272427241124272418
282475245024432435

Table 4. 11: Percentage decrease (%) in hardened density of each pair of mixes**w. r. t control mix at an age of 7 and 28 days****Mix****Age****(Days)****% Decrease w. r. t control mix****0 kg/m³ fibre****2. 0 kg/m³ fibre****2. 5 kg/m³ fibre****3. 0 kg/m³ fibre**

AMS17

-

0. 40. 040. 0428

-

1. 31. 31. 3BMS27

-

0. 700. 428

-

1. 01. 31. 6

Figure 4. 10: Variation of Hardened Density with different fibre content at 7 days

Figure 4. 11: Variation of Hardened Density with different fibre content at 28 days

Observations and Discussions

From Figure 4. 10 and 4. 11, the hardened densities of both MS1 and MS2 specimens decreased slightly compared to the control mix as fibre content increased. It was observed that the decrease in hardened densities of both MS1 and MS2 slightly increased with age. However it could be seen that MS2 showed slightly greater decrease in hardened density than MS1. At 28 days, the net percentage decrease in hardened density was around 1. 3% for MS1 while for MS2, it was noted to be 1. 6%. The hardened density of MS1 varied in the range between 2418 kg/m³ and 2443 kg/m³ while that of MS2 varied in the range between 2411 kg/m³ and 2450 kg/m³. There was not large variation in the results which showed that although the degree of compaction varied, it did not influence the resulting concrete. The densities of the MSFRCs were largely above the range of lightweight concrete, that is 1400-1800 kg/m³ as stated by Neville and Brooks (2007, p. 360). The statement of Richardson (ca. 2005 cited Gold 2000) can account for this slight decrease in hardened densities of both MS1 and MS2; that is as a result of the surface treatment macro synthetic fibres receive in their manufacturing process, they normally incorporate small amount of air bubbles in concrete that are uniformly distributed throughout the cement paste. These small amount of air bubbles are able to displace heavier components in the concrete, thereby lowering the density of the hardened concrete. Another reason may be due to the intersection of the fibres in the

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concrete matrix which may have caused the formation of air voids. As the fibre content in the mix increased, more air voids were formed due to intersection of the fibres which led to decrease in hardened density. Moreover this decrease in hardened density can also be due to the density differences in the concrete. The bulk density of concrete is approximately 2400 kg/m³ whereas that of macro synthetic fibres is around 910 kg/m³. There is a density difference of 2.64 to one. Therefore macro synthetic fibres is of a lower density than that of the surrounding concrete. Hence the hardened density decreases upon addition of the fibres. The same reason as for plastic density holds here to account for MS2 showing slightly greater decrease in hardened density than MS1, that is, the continuously embossed-shaped fibres included in MS2 entrained more air bubbles in the mix or cause greater amount of air voids to be entrapped below or in them than the flat-shaped fibres present in MS1.

4.4.5 Modulus of Elasticity

The results for modulus of elasticity of each pair of mixes are given in Table 4.12 and are illustrated in Figure 4.12.

Table 4. 12: Results for Elastic Modulus for each pair of mixes**Mix****Elastic Modulus (GPa)****0 kg/m³ fibre****2. 0 kg/m³ fibre****2. 5 kg/m³ fibre****3. 0 kg/m³ fibre**

AMS127. 525. 223. 623. 3

% decrease

-

8. 4**14. 2****15. 3**

BMS227. 524. 123. 423. 3

% decrease

-

12.4

14.9

15.3

Figure 4. 12: Effect of Macro synthetic fibres on Modulus of Elasticity

Observations & Discussions

From Figure 4. 12, a decreasing trend in the elastic modulus values was observed for both MS1 and MS2 when compared to the control mix with an increase in fibre content. With increasing fibre content, the elastic modulus for MS1 was found to decrease by 8. 4% to 15. 3% respectively compared to the control mix while for MS2, it decreased by 12. 4% to 15. 3% respectively. It was noticed that the difference between the elastic modulus values of MS1 and MS2 was gradually decreasing as fibre content increased. The decrease in elastic modulus upon addition of macro synthetic fibres can be linked with the fact that macro synthetic fibres promote good bonding with the hardened cement paste and since the modulus of elasticity of the macro synthetic fibre is much less than that of concrete, the latter influences the concrete matrix. The reducing gap between the elastic modulus values of MS1 and MS2 can therefore show that as fibre content increases, both macro synthetic fibres tend to develop similar ductility properties in concrete. Since elastic modulus is inversely proportional to strain, a decrease in elastic modulus leads to an increase in strain. Hence with an increase in fibre content, the elastic modulus of MSFRCs decreases such that there is an improvement in the

strain values of the FRC. Hence the statement of Hasan et al. (2011, p. 22) is confirmed, that is macro synthetic fibres improve the strain values of normal concrete leading to an increase its ductility.

4. 4. 6 Drying Shrinkage

Drying Shrinkage results of each pairs of mixes are shown in Table 4. 13 and is represented in Figure 4. 13.

Table 4. 13: Results for Drying Shrinkage for each pair of mixes

Mix

% Drying Shrinkage

0 kg/m³ fibre

2. 0 kg/m³ fibre

2. 5 kg/m³ fibre

3. 0 kg/m³ fibre

AMS10. 04140. 03590. 03340. 0312

% decrease

-

13. 29

19. 32

24. 64

BMS20. 04140. 03490. 03390. 0321

% decrease

-

15.70

18.12

22.46

Figure 4. 13: Effect of Macro synthetic fibres on Drying Shrinkage

Observations & Discussions

From Figure 5. 11, a general decrease in drying shrinkage was observed with an increase in fibre content for both MS1 and MS2. In other words, the MSFRC specimens shrank less than the control specimen. The difference in drying shrinkage for MS1 between fibre content 2. 0 kg/m³ to 3. 0 kg/m³ and the control mix was found to be 13. 29% to 24. 64% respectively while for MS2, it was found to be 15. 70% to 22. 46% respectively. MS1 shrank more MS2 at fibre content of 2. 0 kg/m³ while it shrank less than the latter at fibre contents of 2. 5 kg/m³ and 3. 0 kg/m³ respectively. The decreasing trend in drying shrinkage of MS1 and MS2 as fibre content increases is due to the fact that macro synthetic fibres inhibit not only water from escaping the concrete by evaporation but also prevent the concrete particles from moving, thus preventing rapid drying of the concrete. The reason why MS1 shrank more than MS2 at fibre content of 2. 0 kg/m³ and thus did not follow the same decreasing pattern obtained at other fibre contents could be due to the presence of more water and less binding medium in the mix. As the fibres found in MS1 were preventing water from escaping, there may have been more pore water trapped in the concrete; hence resulting in more shrinkage

when evaporating. Macro synthetic fibres were found to reduce cracks that were observed mainly on the control specimens. This can be explained by the fibre-matrix formed in the concrete. With the fibres embedded in three-dimensions throughout the concrete, they act as arrestors of propagating cracks formed in the concrete due to drying shrinkage; allowing for uniform distribution of the shrinkage stresses that are developed. Hence drying shrinkage cracks are reduced. Grace Construction Products (2011) states that the addition of macro synthetic fibres in concrete decreases drying shrinkage thereby leading to a reduction in drying shrinkage cracks in concrete. Hence our results confirmed the statement of Grace Construction Products (2011).