

# Experimental Study on Influence of Methylcellulose on Tensile and Flexural Strength of Normal Strength Ordinary Portland Cement Concrete

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RECEIVED ON 27.04.2020, ACCEPTED ON 22.12.2020

## ABSTRACT

Current study explores the possibility of improvement in various categories of concrete's strengths (including tensile strength, flexural strength *etc.*) by using methylcellulose as an additive. The effect of methylcellulose on concrete's compressive strength has also been investigated experimentally. Concrete samples were casted with several methylcellulose to binder ratios varying from 0.002 to 0.01 by weight of cement. Several tests were performed on concrete specimens including concrete cylinder and cube compression tests, split cylinder tests and modulus of rupture tests. Results showed that addition of methylcellulose increased the tensile strength of concrete. Addition of 0.2% of methylcellulose increased the tensile strength of concrete by 16%. This increase in tensile strength reached up to 73% of the control sample on addition of 1% methylcellulose. It was observed that the effect of methylcellulose on compressive strength of concrete depends upon the type of samples being tested (cube or cylinder). The compressive strength of concrete cylinders showed a plateau behavior with peak at 0.4% methylcellulose content with an increase of 18.7%. Effect of methylcellulose on concrete cylinder strength becomes insignificant beyond 0.6%. It was observed that addition of methylcellulose reduces the modulus of rupture values. The reduction in MOR was only 3% at 0.2% methylcellulose content but it grew to 30% at 1% methylcellulose content. The research presents an effective way of increasing tensile strength of concrete but without significant effect on concrete's compressive strength and modulus of rupture values. These findings can be used to determine optimum content of methylcellulose to achieve desired performance from concrete depending upon the intended use.

**Keywords:** Concrete, Tensile Strength, Methylcellulose, Compressive Strength, Admixtures in Concrete.

## 1. INTRODUCTION

Needless to state that concrete is one of the most common choice when it comes to building infrastructure ranging from small houses to large scale buildings. Concrete provides two major advantages as a construction material. One of the major advantages is its conformity to different shapes. The second one is its cost which is usually

quite low due to locally available materials. Although concrete is a versatile construction material, there is a weakness associated with it which is easy susceptibility of concrete to cracking due to tensile stresses. These cracks can affect the strength of concrete as well as reduce the durability of concrete. Cracking in concrete is caused due to lower tensile strength as compared to its compressive strength. It has been reported by several researchers that

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concrete's average tensile strength is usually found to be approximately 10% as compared to the compressive strength. Hence, cracks may appear quickly and may cause other natural phenomenon to effect concrete like alkali—silica reaction and corrosion of steel reinforcement [1, 2].

Several researchers have reported the use of various additives which may help in enhancing various mechanical properties of concrete. Out of these silica fumes, steel fibers, blast furnace slag, recycled aggregates, ferrous-nanoparticles and silica nanoparticles are the most researched items. Several researchers have reported the benefits of adding silica fumes to concrete. Silica fumes and other similar pozzolanic additives increase the tensile and compressive strength of concrete [3]. There are other additives like steel fibers which cause an increase in the tensile strength of concrete without compromising the compressive strength [4]. Ferrous nanoparticles, silica nanoparticles and blast furnace slag may also be used in concrete to enhance the tensile strength of concrete [5, 6].

To mitigate the problems caused by low tensile strength of concrete, various researchers have proposed the use of admixtures in concrete. A similar experimental study reported the use of Methylcellulose (MC) as an admixture to modify mechanical properties of cement paste. It was reported that on adding methylcellulose in cement paste (ranging from 0.2 to 0.8 percent by weight of cement), its tensile strength increases up to 71.9%. However, the use of methylcellulose in cement also caused reduction of compressive strength by around 29.8% [7, 8]. Apart from these parameters, effect of MC on modulus of rupture value of concrete was also examined. Researches have claimed other benefits of methylcellulose as well. A few of them are; to control reinforcement corrosion, improvement in bond strength of concrete and as effective anti-wash admixtures in concrete [9-11].

As very little/scant literature is found on the use of methylcellulose as mechanical property enhancing additive, authors feel a need to investigate this material for potential use as strength enhancing additive in

concrete. Major objective of this study is to use methylcellulose as an additive in concrete and study the effect on various mechanical parameters of concrete.

## 2. MATERIALS AND METHODS

To study the effect of MC on mechanical properties of concrete, varying quantities of MC were added to concrete mix (0.2% to 1.0% by weight of cement) which has been discussed in detail later. Concrete cubes and cylindrical specimens were casted to investigate the various mechanical properties of concrete. All tests were limited to 28 days to replicate the field practice. Cement mortar cubes were also casted to study the effect of MC on properties of cement matrix. The details of materials, specimens casted and tests planned have been discussed in later sections;

### 2.1 Specimen Details

Different types of concrete samples were casted in this study. Cylinder specimens with 150mm diameter and 300mm depth were casted to perform split cylinder tests following ASTM C496 [13]. Several researchers have discussed that biaxial tensile strength of concrete is comparable to uniaxial tensile strength [14], hence only split cylinder tests were selected for this research. 300mm high and 150mm diameter cylinders and 150mm cube specimens were casted to study the concrete compressive strength following ASTM C39 / C39M - 17b (2017) and BS 1881-116 (1983) [15, 16]. 50mm cement mortar cubes were also casted to study the influence of MC on mechanical properties contributed by cement. For this ASTM C109 was followed [17]. Concrete prisms (100mm × 100mm × 500mm) were also casted to study the effect of MC on flexural strength of concrete using modulus of rupture test. ASTM C78 / C78M - 16 (2016) was followed to determine the modulus of rupture test [12]. Fig. 1 shows the type of specimens casted and curing technique used.

Samples were casted using concrete shear force pan mixer and its compaction was done using needle vibrators. Six different mixtures were investigated by

varying the dosage of MC by weight of cement. The dosage varied from 0% to 1%. The IDs and dosage values have been given in Table-1. The curing of samples was carried out after 24 hours (demolding time). For effective curing, these samples were submerged in water (Fig. 1).



Fig. 1: Casting and curing of concrete & mortar specimens

## 2.2 Materials Used

The commonly available OPC cement was used in this study. The physical properties of cement were determined (as reported in Table 2) to check its compliance to ASTM C150 Type-1. Methylcellulose was added to concrete by weight of cement. Powered Methylcellulose was used as an admixture in concrete. Methylcellulose was composed of 1.6-1.9 mol of methoxy per mol of cellulose (27.5-31.5 wt. % methoxy). There were six different concrete mixes produced with methylcellulose content being 0%, 0.2%, 0.4%, 0.6%, 0.8% and 1% by weight of cement. The specimen designations corresponding to each dosage have been given in Table 1. Fine aggregate (sand) conforming to ASTM-C33 was utilized [18]. The local name of this fine aggregate is Lawrencepur sand (named after its source area). The sand was well graded as evident from the gradation chart given in Fig. 2. Coarse aggregate (crush) having maximum size of 20mm conforming ASTM C33 was used in Concrete mix. The local name of this aggregate is Margalla Crush (named after the source area). This aggregate was well graded as evident from the

gradation chart given in Fig. 3. The concrete used in this study was produced according to American Concrete Institute Committee 211 (1997) [19]. Mix design ratio was kept 1:2:4 with water-binder ratio of 0.6 as methylcellulose cause a reduction in workability of concrete (studied in a separate research project in the same institute). Target 28 days compressive strength was around 20 MPa.

Percentage MC (% by weight of cement)	Specimen Designation
0% (Control Sample)	BS1
0.2%	BS2
0.4%	BS3
0.6%	BS4
0.8%	BS5
1.0%	BS6

Properties	Cement
Normal Consistency (%)	29.3
Initial setting time (min)	103
Final setting time(min)	220
Specific gravity	3.65
Specific surface area (m <sup>2</sup> /Kg)	340

## 3. RESULTS AND DISCUSSION

Tests were performed at 28 days after casting of concrete specimens. 28 days strength was used to keep the study in line with current field practices. Rate of gain of strength observations show a similar trend between control sample and samples with different MC content which means that using concrete with MC at 28 days of casting might be a reasonable assumption.

### 3.1 Effect of MC on Tensile Strength of concrete

The prime purpose of this study was to investigate the effect of MC on concrete's tensile strength and for that purpose concrete split cylinder test was conducted. Table 3 and Fig. 4 show the average of 7 split cylinder test results corresponding to each sample type (BS1-BS6). With addition of MC to concrete, an increase in the tensile strength was observed. Concrete samples

without MC provided an average tensile strength of 1.268 MPa which is 6% of the cube compressive strength casted with same concrete at the same time (21.098 MPa) and 6.5% of cylinder compressive strength (19.744 MPa). Specimen BS2 (with 0.2% MC content) showed tensile strength of 1.474 Mpa which is 8.8% of cube compressive strength (16.793 MPa) and 7.4% of cylinder compressive strength. These results show 16% increase in the tensile strength of concrete on addition of 0.2% MC in concrete mix. Specimen BS3 with 0.4% MC content had a tensile strength of 1.611 MPa which is 27% more than the control specimen BS1 and 9.3% more than BS2 specimens. Average tensile strength of BS6 specimens was found out to be 2.194 MPa which is 73% more than BS1 control specimen. Fig. 4 (a) shows the rate of increase in tensile strength which remains nearly

constant up to 1.0% MC content. This increase in the tensile strength of concrete on addition of methylcellulose can be attributed to its fiber like properties which were reported [20]. An Scanning Electron Microscope (SEM) image of methylcellulose is shown in Fig. 5. The methylcellulose presumably acts as fibrous material in concrete causing an increase in tensile strength. Several other research studies have reported that fibers have positive effect on the tensile strength of concrete. A similar study reported that that methylcellulose can be used to improve the tensile strength of normal strength OPC concrete, but its effect on compressive strength was not significant. Hence, further investigation is required to study MC's impact on concrete compressive and flexural strength [9, 21].

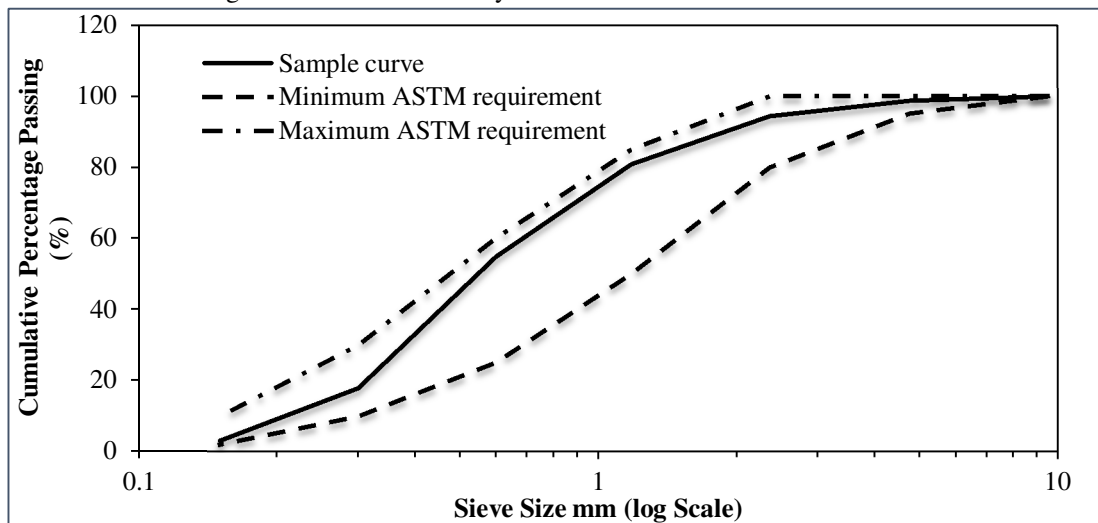


Fig. 2: Gradation curve for fine aggregate (Local Name Lawrencepur Sand)

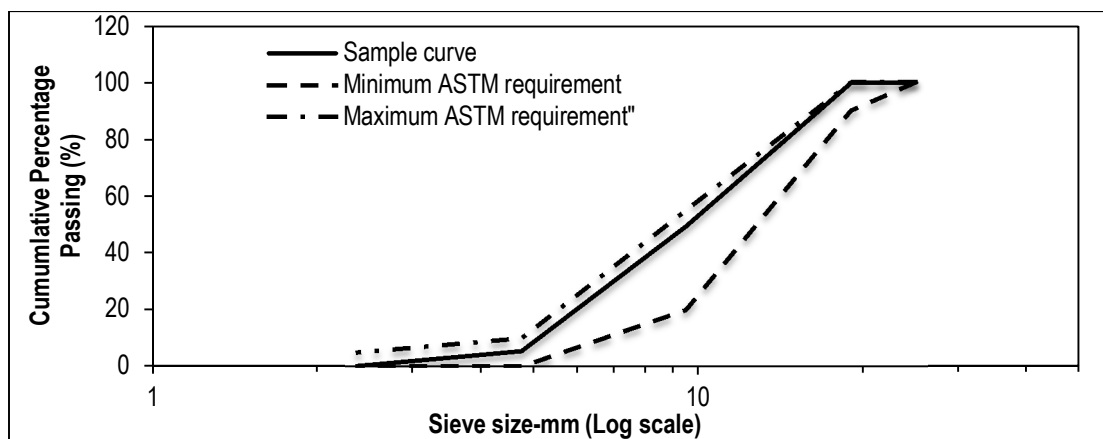
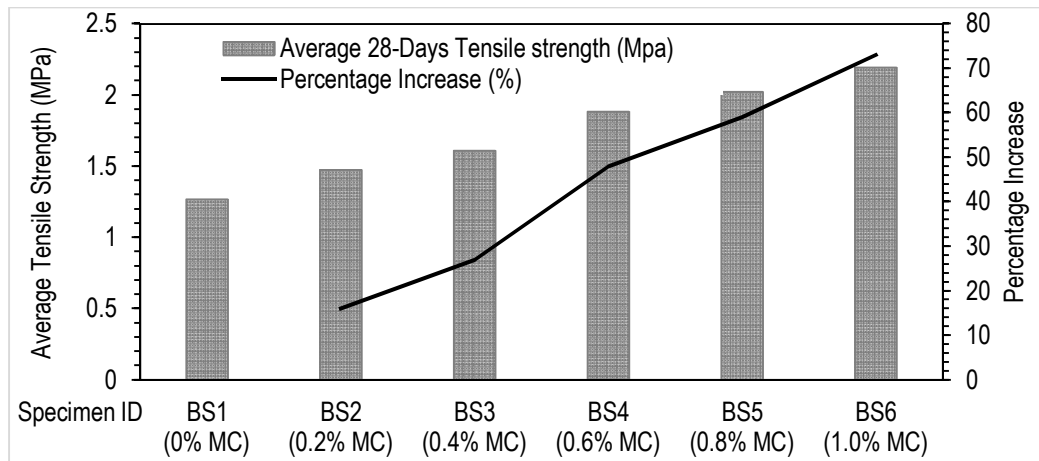
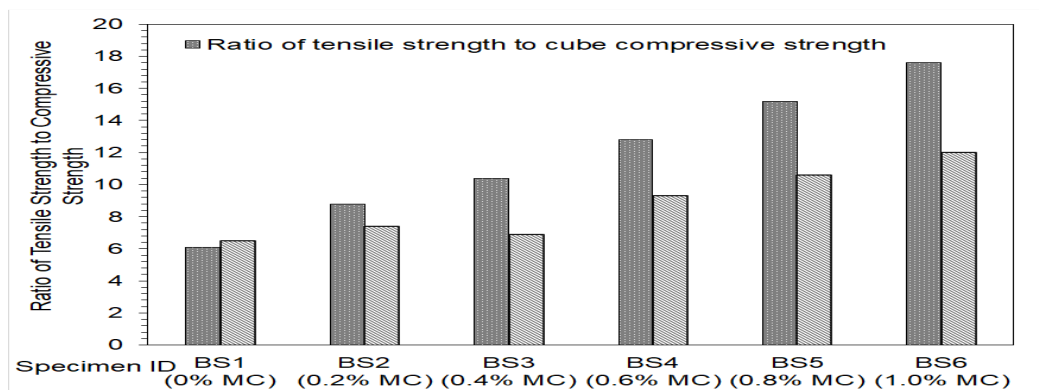


Fig. 3: Gradation curve for coarse aggregate (Local Name: Margalla Crush)



(a): Tensile strength of concrete specimens with 0%-1% MC content



(b) Ratio of Tensile Strength to Compressive Strength

Fig. 4: Effect of MC on Tensile Strength (a) Tensile strength of concrete specimens with 0%-1% MC content (b) Ratio of Tensile Strength to Compressive Strength (1 MPa = 145.04 psi)

Sr. No.	Specimen ID	Average 28-Days Tensile strength MPa (psi)	% Increase	Ratio of tensile strength to compressive strength	
				w.r.t cube str	w.r.t cylinder str
1	BS1	1.268 (183.91)	0	6.1	6.5
2	BS2	1.474 (213.78)	16	8.8	7.4
3	BS3	1.611 (233.65)	27	10.4	6.9
4	BS4	1.884 (273.25)	48	12.8	9.3
5	BS5	2.023 (293.4)	59	15.2	10.6
6	BS6	2.194 (318.2)	73	17.6	12

### 3.2 Effect of MC on Compressive Strength of Concrete

To determine the effect of MC on compressive strength of concrete, cubes and cylinders were tested.

ASTM C39 was followed to test concrete cylinders while BS 1881-116:1983 was followed to test concrete

cubes. Concrete cubes were selected to make it easier to compare the effect of MC on compressive strength with cement mortar cubes and avoid the poison's effect present in cylinders.

Table 4 and Fig.6 present the result of concrete compressive strength corresponding to concrete

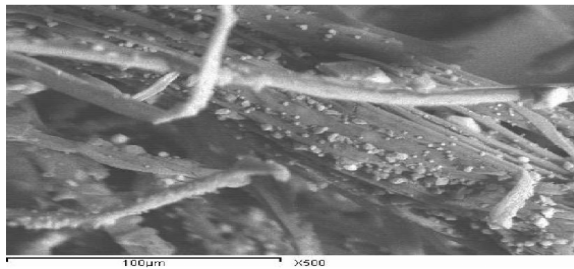


Fig 5: SEM for Methyl Cellulose Ibrahim *et al.* [20].

cylinder samples while Table 5 and Fig.7 present the results of concrete cube samples. Concrete cubes tests show that the presence of MC in concrete mix cause a reduction in cube compressive strength of concrete while the cylinder compressive strength shows a plateau effect. The reduction in concrete cube compressive strength goes parallel with the cement mortar cubes test results.

Sr. No.	Specimen ID	Average 28-Days Compressive strength MPa (psi)		% Decrease
		Cylinder Specimen	Cube Specimen	
1	BS1	19.744 (2863.67)	21.098 (3060.05)	0
2	BS2	19.847 (2878.61)	16.793 (2435.66)	20
3	BS3	23.429 (3385.67)	15.610 (2264.07)	26
4	BS4	20.343 (2950.55)	14.748 (2139.05)	30
5	BS5	19.244 (2791.15)	13.349 (1936.14)	36
6	BS6	18.332 (2658.87)	12.489 (1811.40)	40

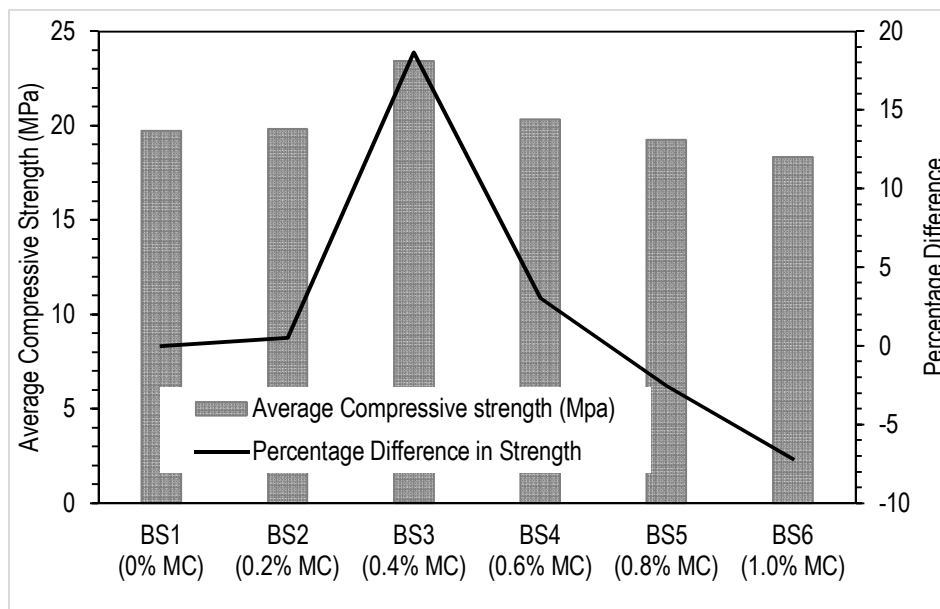


Fig. 6: Compressive strength of concrete cylinder specimens with 0%-1% MC content (1 MPa = 145.04 psi)

Sr. No.	Specimen ID	28-Days Compressive Strength MPa (psi)	% Decrease
1	BS1	37.755 (5475.98)	0
2	BS2	25.918 (3759.15)	31
3	BS3	21.424 (3107.34)	42
4	BS4	16.837 (2442.04)	55
5	BS5	13.367 (1938.75)	64
6	BS6	9.8 (1421.39)	74

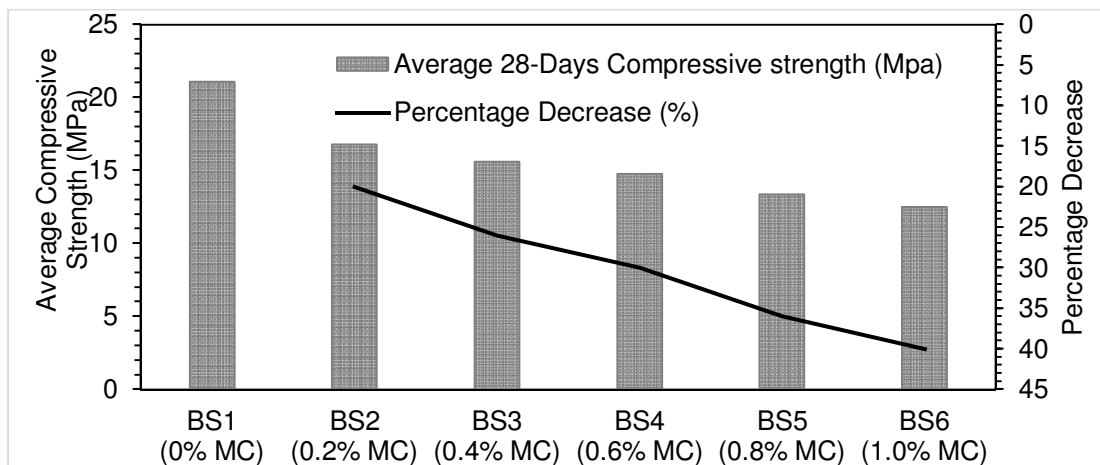


Fig. 7: Compressive strength of concrete cube specimens with 0%-1% MC content (1 MPa = 145.04 psi)

In case of cylinder specimen, on addition of 0.2% MC the concrete compressive strength increased from 19.74 MPa to 19.85 MPa which is insignificant. But on addition of 0.4% and 0.6% MC the strength increased to 23.4 MPa and 20.3 MPa respectively. Up to MC content of 0.6% the compressive strength was observed to increase but on increasing MC beyond 0.6% the strength reduced below the control sample. With 0.8% and 1.0% MC content the compressive strength was 19.24 MPa and 18.33 MPa respectively. Concrete cylinder tests exhibited 18.7% increase in the compressive strength on addition of 0.4% methylcellulose. While this increase was insignificant on addition of 0.2% MC. On increasing the amount of methylcellulose more than 0.6% the concrete compressive strength started dropping to a maximum of 7% for BS6 specimens (1.0 % MC).

Concrete cube specimen BS2 having 0.2% MC content showed a reduction of 20% in the compressive strength while specimen BS6 with 1.0% of MC exhibited 40% reduction in concrete compressive strength which is a large value. This specimen had exhibited an increase of 73% in its tensile capacity. The detailed results of concrete cube compressive strength tests have been given in Table 4 and Fig.7. Fig. 8 shows the rate of gain of strength of concrete samples with different MC contents. This study was carried out to observe the development of strength in concrete samples. The rate of gain of strength in all samples (BS1-BS6) is similar to control sample.

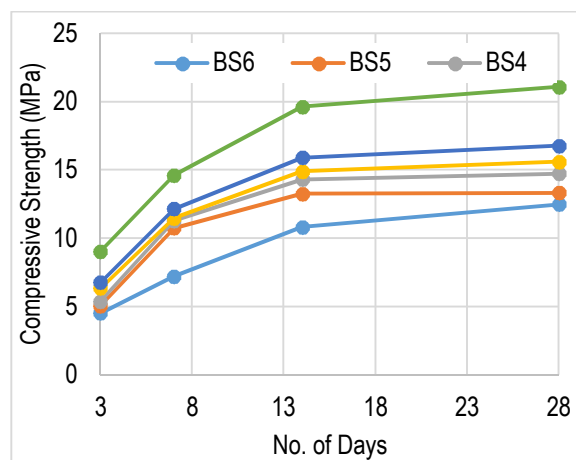


Fig. 8 Rate of gain of strength, concrete cubes (150mm x 150mm)

Results show that MC's effect on compressive strength of concrete also depends up on the type of specimen being tested. Concrete compressive strength from cylindrical specimens is affected by concrete tensile strength but this is not the case with concrete cubes. This might be one reason for opposite trend observed while testing concrete cubes and cylinders. Fritih *et al.* [21] and Balendran *et al.* [4] has reported that steel fibers have similar effect on the mechanical properties of concrete [9, 21]. Steel fibers cause an increase in the tensile strength of concrete while their effect on the compressive strength of concrete is insignificant. Hence, it can be concluded that methylcellulose has similar effect on the tensile and compressive strength of concrete.

These results provide a guideline to select an optimum amount of methylcellulose to give a good compromise between the compressive and tensile strength of concrete for specialized uses.

### 3.3 Ratio of Cube Strength to Cylinder Strength Ratio

Elwell and Fu [22] reported that compressive strength obtained from concrete cylinder specimens usually range between 0.65 to 0.9 times the compressive strength obtained from cube specimens [22]. Experimental results of author's research (Fig. 9) show that at 0% MC content, average compressive strength of concrete cubes was 21.098 MPa while the compressive strength of concrete cylinders was 19.744 MPa which was 0.94 times the cube compressive strength. At 0.2% MC content, the concrete cylinder strength was observed as 19.847 MPa which was 1.18 times that of concrete cube strength (16.793 MPa). At 1% MC content, this ratio increased to 1.5. This change in strength can also be attributed to the enhanced tensile strength of concrete due to addition of methylcellulose. The effect of fibrous materials on tensile strength has already been discussed based on experimental observations. It has been already reported by other researchers that fibers may not increase the compressive strength of concrete [4], similarly the effect of MC on the compressive strength of concrete is not significant up to lower dosage.

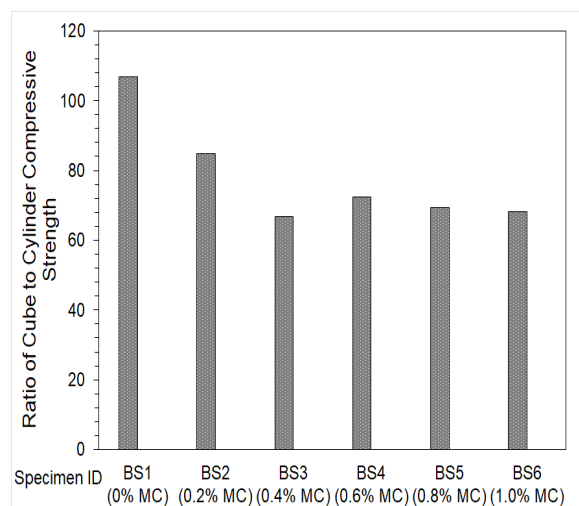


Fig. 9: Relationship of MC content and the ratio of cube to cylinder compressive strength

### 3.4 Effect of MC on Compressive Strength of Mortar Cubes

Apart from concrete specimens, cement mortar cubes were also casted and tested following ASTM C109 and the results have been shown in Table 5 and Fig. 10. The results showed that the effect of methylcellulose was similar (but with different strength values) on both concrete cubes and cement mortar cubes (under compression testing) as shown in Fig. 10. Cement mortar cube compressive strength of control sample was observed to be 37.75 MPa. This strength reduced to 25.92 MPa at 0.2% MC and 13.37 MPa at 0.8% MC. The reduction at 0.2% MC and 0.8% MC was 31% and 64% respectively. The reduction in strength of cement paste cubes was larger as compared to concrete cubes. This might be due to the presence of coarse aggregates in concrete samples which have considerable contribution towards the compressive strength of normal strength concrete. As the failure in normal strength concrete is governed by the cement-sand matrix, the effect of methylcellulose on cement cubes and concrete cubes remains similar.

### 3.5 Effect of MC on Flexural Strength of concrete

In order to study the effect of MC on flexural strength of concrete modulus of rupture tests were performed following ASTM C78. Concrete prisms were casted 500mm long and 100mm square cross section. These were tested under two-point loading test as shown in Fig. 11. Results (Table 6 and Fig. 12) show that the modulus of rupture value decrease with an increase in MC content.

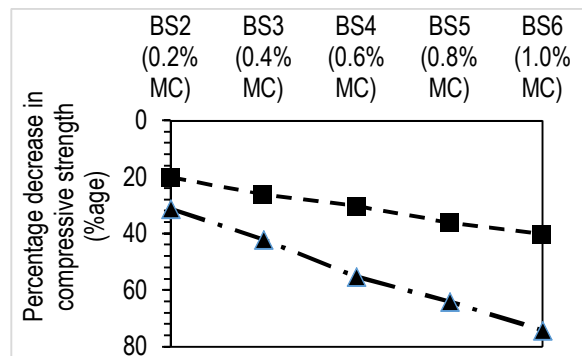


Fig. 10: Comparison of increase in compressive strength of concrete cubes and cement mortar cubes on same scale



Sr. No.	Beam ID	28-Days Flexural Strength MPa (psi)	% Decrease
1	BS1	6.297 (913.31)	0
2	BS2	6.055 (878.22)	3
3	BS3	5.719 (829.48)	9
4	BS4	5.328 (772.77)	15
5	BS5	4.844 (702.57)	23
6	BS6	4.359 (632.23)	30

Modulus of rupture value at 0.2% MC was observed to be 6.06 MPa while the corresponding value of control sample was 6.29 MPa. This reduction in MOR is 3% at 0.2% MC content while the tensile strength at the same MC content had increased by 16%. The concrete cylinder compressive strength at 0.2% MC was nearly same but the concrete cube compressive strength reduced by 20%. This shows that the MOR value is directly affected by the cube compressive strength. Same trend was observed with other samples *i.e.*, at 0.4% MC content, MOR reduced by 9% while concrete cylinder strength increased by 18.7% and concrete cube strength reduced by 26%.

Experimental observations on MOR values show that its relationship with concrete cube strength is stronger than concrete cylinder strength. As the concrete cube strength reduces, the MOR also reduces regardless of the increase in concrete tensile strength. To put it in broader perspective, we should consider that at 0.2% MC the tensile strength of concrete increased by 16% while concrete cube strength reduced by 20%. Combined effect of these caused a reduction of 3% in MOR value of concrete.



Fig. 11: Modulus of rupture test

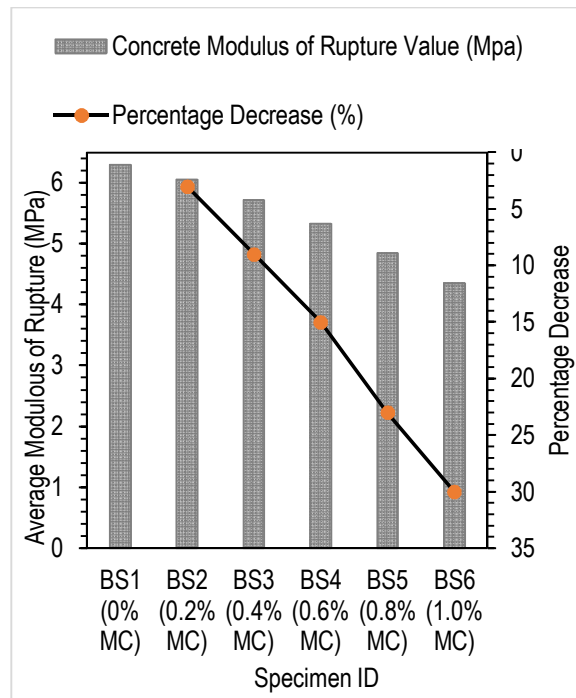


Fig. 12 Modulus of Rupture value of concrete specimens with 0%-1% MC content (1 MPa = 145.04 psi)

#### 4. CONCLUSIONS

An extensive research study was carried out primarily including experimental work to investigate the impact of methylcellulose on mechanical properties of concrete including its compressive and tensile strengths. The experimental results clearly show that the tensile strength of concrete can be improved by adding methylcellulose. On addition of 0.2% methylcellulose, tensile strength of concrete increase by 16% and this value keeps increasing with further increase in methylcellulose content. The effect of methylcellulose on concrete's compressive strength vary with the type of samples/tests being carried out. Compressive strength of concrete cylinders exhibits a plateau effect with its peak at 0.4%. The compressive strength of concrete increase by around 18.7% at 0.4% methylcellulose addition. In case of concrete cube samples, the compressive strength reduces on addition of methylcellulose. This reduction is insignificant at low methylcellulose content while it increases significantly at larger methylcellulose contents. Hence it can be stated that a complex relationship exists between concrete tensile strength and concrete

compressive strength obtained from cube and cylinder specimens. These combined results can be used to determine an optimum content of methylcellulose to achieve desired performance from concrete depending upon the intended use. Although a value ranging between 0.2% to 0.6% may be considered based upon the desired performance, 0.4% may be considered as overall optimum value due to an increase in the tensile strength and compressive strength (cylindrical specimen) at the same time.

## ACKNOWLEDGMENT

We would like to thank Civil Engineering Department, University of Engineering and Technology Lahore for providing testing facilities for the research work published in this article.

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