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EVALUATION OF MECHANICAL PROPERTIES AND FLEXURE BEHAVIOUR OF HIGH PERFORMANCE HYBRID FIBRE REINFORCED CONCRETE – A REVIEW

N.V.N.Prabath[1]
Research Scholar,
Department of Civil Engineering, Pondicherry Engineering College, Puducherry, India

Dr.P.Ramadoss[2]
Professor,
Department of Civil Engineering, Pondicherry Engineering College, Puducherry, India

Abstract: High-performance concrete (HPC) is a material frequently used in the building industry due to its durability. Concrete technology has developed at a rapid pace over the last two decades and the material performance has been significantly improved. Now a day, there are numerous types of fibres made of different materials that are of different geometric properties. With each type of fibre certain properties of concrete can be improved. In order to improve mechanical properties, especially the tensile and flexural strengths and long-term concrete shrinkage, steel fibres' are usually used. One of the recent concepts is the hybridization of fibres, the optimum combination of several kinds of fibres with different properties to create a complex composite with a very high resistance to cracking in a wide range of crack width. A lot of research revealed that a hybrid of steel and polypropylene fibre in concrete exhibits composite advantages of the two-fibre material properties, improves the interface condition between cement and aggregate, enhances the medium continuity of concrete, and constraints the occurrence and development of concrete cracks. Present study focussed on the rational development of researches on hybrid fibres from past decades and objectives of future enhancement.

***Key words**: Review on hybrid fibre RC, properties study, future applications.*

1.0 INTRODUCTION: High - strength concrete is particular where reduced weight is significant or where architectural considerations require smaller load-carrying elements, high strength concrete helps to get more well-organized floor plans through smaller vertical members and has also often established to be the most economical alternative by reducing both the total volume of concrete and the amount of steel required for a structural members [1]. However, high strength concrete when subjected to short term or sustained loads tends to be brittle. This performance of high strength concrete raises questions about the application of the material to structures, mainly in earthquake regions. Addition of fibres in concrete improve the tensile characteristics by inhibiting crack growth and increase in toughness or energy absorption capacity, flexural strength, fatigue resistance and ductility [2,3]. Various types of fibres were used in concrete such as metallic

fibres, polymeric fibres, mineral fibres, and naturally occurring fibres, among these steel fibres are giving better performance due to their high modulus of elasticity and tensile strength. Concrete with steel fibres have been generally used in the building industry applications such as industrial and airport pavements, reinforcement of projected concrete, and precast elements.

2.0 Objectives:

- To review the different researches made on hybrid fiber reinforced concrete.
- To understand the behaviour of HFRC with different combinations.
- To study the behaviour of HFRC by using steel fibres.
- To study the behaviour of HFRC with Polymer fibres.

2.0 Literature review: [1] W. Sun, H. Qian, H. Chen,(2000). Durability is the ability to last a long time without significant deterioration. Hybrid fiber reinforced concrete (HFRC) proves to be durable material, which is effective in resisting the damage caused due to freezing and thawing due to synergistic performance of hybrid fibers.It has been concluded that the performance of hybrid fibers in concrete is better than that of mono fiber concrete for improved durability in resisting the destructive effect of freezing and thawing and also for strength enhancement.**[2] Banthia, N., Yan, C., Bindiganavile, V. (2000).**To develop High Performance Fibre Reinforced Concrete(HPFRC). Towards an efficient utilization of binders and fibres in HPFRC, the modified Andresen & Andersen particle packing model and the hybridization design of fibers are utilized.The HPFRC mixtures with hybrid fibres have higher strengths than those with a single type of fibres. The macro-fibres (hooked steel fibres) can also be utilized to produce HPFRC, with good mechanical properties. **[3] Qian, C.X. and Stroeven, P. (2000).**This study report deals with the reinforcing efficiency of hybrid fibres in the low volume fly ash concrete up to 30% replacement of cement. Micro mechanical action of hybrid fibres in fly ash based concrete will be improved with respect to different percentage of steel and polypropylene fibre addition. The optimum level of fly ash replacement should be between 10 to 30% in order to obtain maximum strength of the concrete. If fly ash replacement level up to 60%, concrete gains its strength only after 90 days of curing The increase in percentage of steel fiber results only in increase of tensile strength. **[4] Skazlić, M. (2001).**a review on the high performance high volume fly ash concrete reinforced with hybrid fibers.tried to substitute fly ash for cement which generally leads to lower strength.it is clear that steel fiber (high modulus fiber) which is stronger and stiffer, improves the concrete strength, while polypropylene fiber has the capacity to strengthen brittle cementitious materials and is more flexible and has the property to retain heat for a prolonged time which leads to improved toughness, and strain capacity in the postcracking section and retard early cracks.**[5] Naaman, A.E., and Reinhardt, H.W.,(2001)**The describedmaterials were specifically developed for application as a transition layer: a repair layer that constitutes the stressed chord of reinforcedconcrete beams strengthened in flexure with carbon fiber reinforced polymers (CFRP). the hybridization process is an interesting alternative for application in the recovery of tensile bottom chord of beams, once the addition of microfibers to the steel fibres' increased the tensile

stress in flexure and increased the flexural tenacity of the cement-based mortar and microconcrete composites. **[6]Alwan JM, Naaman AE, Hansen W.(2002)** Pull The use of high performance composite fibers allows for the improvement of the mechanical properties of cement composites. Mechanical properties of such composites are determined predominantly by the interface properties between the fiber and cementations' matrix.Composites using single-fiber pull-out tests. For this purpose, the study presents the characteristics of both fiber-matrix interfacial properties and fiber rupture. The results of these tests allow specific design parameters to be evaluated quantitatively. **[7]Y. Liu, W. Qiu, D. Li, (2003)**.Polypropylene Fiber Reinforced Concrete is an embryonic construction material which can be described as a concrete having high mechanical strength, Stiffness and durability. Polypropylene fibers are versatile and widely used in many industrial applications such as ropes, furnishing products, packaging materials etc.Polypropylene Fiber reinforced Concrete is used in roads and pavements, drive ways, Overlays and toppings, ground supported slabs, Machine foundations.**[8] Chanvillard G, Rigaud S.(2003**a model-based analysis of the risk of early age cracking in structures made of High Performance Concrete (HPC). First, we summarize the background works on modellingHPC at early age with emphasis on the thermodynamics hypothesis of partial decoupling which substantially simplifies the application and calibration of the model. The effect of hydration heat can be critical for HPC structures with size larger of 20-30 cm, which is the critical diffusion length; The concept of level of loading was used as indicator of risk of early age cracking. Furthermore, a preliminary probabilistic approach was presented as powerful tool to identify the impact of material parameters on the risk of cracking. **[9] Banthia, N., Nandakumar, N. (2003).**to use of different fiber as reinforcement in concrete for a greater durability, workability and reduction in crack. The present work is concerned with the compressive strength of FRC specimens (132 cubes) with 90 days of normal water curing and 90 days curing in sulphate& chlorideThe fiber orientation plays an important role to determine the compressive strength, which depends on the mixing. FRC controls the micro cracking, shrinkage and deformation under load much better than plain concrete. **[10]Song PS.(2004).**The various strength properties studied are cube and cylinder compressive strength, split tensile strength, modulus of rupture and post cracking performance, modulus of elasticity, Poisson's ratio, and strain corresponding to peak compressive stress.The maximum increase in the compressive strength, modulus of elasticity, and Poisson's ration due to the addition of steel fibers was found to be quite small less than 10% in various grades of concrete 35, 65, and 85 MPa. The maximum increase in the strain corresponding to the peak compressive strength was found to be about 30% in various grades of concrete 35, 65, and 85 MPa.**[11] RILEM PRO (2004)**to study the effect of fibre hybridization on the strength characteristics such as compressive strength, split tensile strength, and water permeability of steel fibre reinforced concrete (SFRC) are presented. Combinations of steel fibres of different lengths and plain concrete in hardened state have been investigated. Tests such as compressive strength, split tensile strength, and water permeability were conducted on hardened concrete after 7, 28, 90, and 120 days of

curing. **[12]N. Banthia, R. Gupta,(2004)**Nylon fiber is not an absolutely new material, it is successfully applied in such fields as mostly found in garment interlinings, tooth brush, Fishing lines, Nets and building structures. Finally we have come to a conclusion that Nylon Fibre Reinforced Concrete has far better strength than normal concrete. Nylon Fibre Reinforced of 1%, 2%, 3% and Normal Concrete and also found that adding 1% Nylon of total volume of concrete achieves more strength than that of normal concrete.**[13] Lawler J, Zampini D, Shah S. Micro (2005)**Since many decades efforts have been made to reduce the brittleness of cementations' materials by the use of micro and macro fibers of different mechanical, geometrical and physical properties.Maximum load bearing capacity (peak load), residual flexural strength and flexural toughness unreinforced matrix are significantly increased by the addition of metallic fibers. **[14] J.A.O. Barros, E. Pereira, A. Ribeiro, V. Cunha,(2005)** experimental study and technical details of the suggested technique along with those of the traditional sandwich panels are presented. The experimental work is conducted on full scale specimens to verify the applicability and efficiency of the proposed method. Results indicated that the ultimate loads, failure modes, and load deflection relationships of the proposed walls are greatly improved by using the suggested technique.A large increase is observed of yield and ultimate load-carrying capacities of the proposed technique specimen compared to reference sandwich panel ones.**[15] Wang C, Yang C, Liu F, Wan C, Pu X.(2005)**The construction of high-rise buildings and mega projects around the world, and the increasing demands of owners and designers have led to the increasing demand on High Strength Concrete (HSCan intensive study has been made on the development of High Strength Concrete. Three different concrete mixes have been used to get High Strength Concrete. Cubes, cylinders and prisms have been cast using this three different mixes and their properties in fresh and hardened states have been experimentally found out.**[16]Markovic I.(2006)** Hybrid Fiber Concretes (HFC) are newly developed cement composites, whose main characteristic is utilization of different types of steel fibres in high-strength mortar mixtures. Although the flexural behavior was very superior, the determination of uniaxial tensile behavior is necessary to provide a basis for design.The uniaxial tensile behavior of a number of mono - and hybrid-fibre reinforced concretes was estimated. Maximum applied fibre volume was 2 vol.-% (160 kg/m3). Tensile tests were performed on unnotched and on a couple of notched "dogbone" specimens.**[17] Habel K, Viviani M, Denarie E, Bruhwiler E.(2006)**this paper investigate the effect of steel fiber (volume fraction and aspect ratio) on the mechanical properties of high performance concrete such as, Compressive strength, modulus of elasticity, Poisson's ratio, flexural strength and tensile strength.his research show that it is possible to produce HPFRC using available local materials that if they are carefully selected. Such concretes can be produced with ordinary Portland cement, silica fume, steel fibers, super plasticizer, fine sand and basalt with ratio as discussed before.**[18] Banthia, N. and Gupta, R., (2006)** .Plastic shrinkage cracks are especially harmful on slabs. One of the methods to reduce the adverse effects of shrinkage cracking of concrete is by reinforcing concrete with short randomly distributed fibers. A significant reduction in water bleeding is

observed for concrete series B compared to concrete series A for all concretes. first crack initiation time for series B plain concrete is two times higher compared series A plain concrete. **[19] Naaman AE.(2007)**the fiber material (steel, synthetic, natural organic) or the level of performance, a general, It is based on the response of the composite under tensile loading, which can be described as either strain softening after first cracking, or strain hardening.This impetus may be partly due to fundamental research, better understanding of the reinforcing mechanisms of FRC composites, the need for materials with particular properties, developments in advanced materials, economic competitiveness, and global circumstances. A solid foundation has thus been built.**[20] M. di Prisco (Ed.),(2007).**The lightweight, high strength and corrosion resistance of fiber reinforced polymers (FRP) make them ideally suited for quick and effective structural repairs. The motivating premise of all the repair options considered was that external confinement in the form of jacketing could alter favorably the process of corrosion by slowing down the rate of the corrosion reaction, and imparting ductility and strength to the affected structural element. FRP wraps, being strong and corrosion-resistant, proved very effective as jacketing material.**[21] Kim DJ, El-Tawil S, Naaman AE.(2007)**the study is to study the effect of glass fibre and steel fibers in the concrete. In the present work the strength studies are carried out to compare the glass and steel fiber concrete. In compressive strength, flexural strength and split tensile strength, the addition of Steel fiber the strength is increasing linearly, but in glass fiber up to 1% it is increasing and from 2% it is decreasing. It is concluded that the strength is increasing while increasing the percentage of steel fiber. **[22] Kim DJ, Naaman AE, El-Tawil S,(2007)**a steel fibers in a concrete matrix improves all the mechanical properties of concrete, especially tensile strength, impact strength, and toughness. The resulting material possesses higher tensile strength, consolidated response and better ductility.The suggested equation correlates the split tensile strength of steel fiber reinforced concrete with concrete compressive strength and fiber reinforcement index Concrete compressive strength, fiber content and the fiber aspect ratio are the major effectual parameters in specifying the tensile strength of fiber concrete.**[23]C. Yang, C. Huang, Y. Che, B. Wang,(2008)** The effect of addition of mono fibers and hybrid fibers on the mechanical properties of concrete mixture is studied in the present investigation. Steel concrete mixture as mono fibers and then they were added together to form a hybrid fiber reinforced concrete**.** It is evident from the present investigation that the hybridization of fibers proves to be better as compared to mono fibers.The improved mechanical properties of HFRC would result in reduction of warping stresses, short and long term cracking and reduction of slab thickness.**[24] Graybeal B, Davis M.(2008)**Mixing of horsehair and straw with the clay to form floor and bricks was one of the earliest example in which fiber was utilized to strengthen a brittle matrix. then, a plethora of books and papers have been published on the use of various fibers in cement-based material. Workability of the fresh mix is adversely affected by the addition of fibers and further decreases by increasing the fiber volume fraction. No particular trend is observed in compressive strength due to addition of fibers. Flexural and tensile strength, ductility,

drying shrinkage and toughness of the material is usually benefited by the addition of fibers.**[25] Jungwirth J, Muttoni A.(2008)** As continued research on High Performance Concrete (UHPC) becomes more readily available, researchers are becoming increasingly interested in developing new structural applications for the material. **[26] Sivakumar A.(2009)**Concrete is the mostly used construction material in the world but there is a disadvantage of concrete that it is week in tension. This results to the brittleness of concrete. This property is not desirable for any kind of construction so there is requirement of tensile reinforce. Steel fiber reinforced concrete is basically defined as a composite material which consist of steel fiber of specific characteristics like random distribution and specific size and volume as compare to the conventional reinforced steel bars the steel fibre are thin, short and randomly distributed in the concrete.**[27] J. C. Walraven, (2009)**Sustained post cracking tensile resistance is a fundamental mechanical characteristic of high-performance fiber-reinforced concrete This research program developed a simple, reliable direct tension test (DTT) method that can generate the uniaxial tensile mechanical response for both cast and extracted samples.A foundation from which a reliable, practical method to directly capture the uniaxial tensile stress-strain response of HPFRC can be created. The developed test method meets critical test requirements, including the ability to be completed relatively quickly on either cast or extracted specimens through the use of commercially available testing equipment.**[28] M. di Prisco, G. Plizzari, L. Vandewalle,(2009).** A Fiber Reinforced Concrete (FRC) is a composite material consisting of cement based matrix with an ordered or random distribution of fiber which can be steel, nylon, polythene etc. Development in technology enhances not only human comforts but also destroy the eco-system. Fiber Reinforced Concrete is generally made with high M40 grade cement content & low water content.Steel Fiber 1.5% addition improves ductility of concrete & its post-cracking load carrying capacity. Increases the cube compressive strength 40.00 Mpaconcrete in 7 days The most important contribution of fibre reinforcement in concrete is not to strength but to the flexural strength 18% concrete materials. **[29] F. Bencardino, L. Rizzuti, G. Spadea, R. N. Swamy,(2010**) Concrete is characterized by brittle failure, the nearly complete loss of loading capacity, once failure is initiated. This characteristic, which limits the application of the material, can be overcome by the inclusion of a small amount of short randomly distributed fibers and can be practiced among others that remedy weaknesses of concrete, such as low growth resistance, high shrinkage cracking, low durability .Fiber addition improves the strength parameters of concrete. This may be due to the high energy absorbing capacity of fibers. Fracture properties show an increasing variation with an increase in fiber content from 0.5%to 1% due to the crack resisting property of steel fibers.**[30] S. P. Singh, A. P. Singh, V. Bajaj,(2010)**investigation conducted to study the effect of fiber hybridization on the strength characteristics such as compressive strength, split tensile strength, and water permeability of steel fiber reinforced concrete (SFRC) are presented. Properties of HSFRC containing different combinations of steel fibers of different lengths and plain concrete in hardened state have been investigated. Tests such as compressive strength, split tensile strength,

and water permeability were conducted on hardened concrete after 7, 28, 90, and 120 days of curing. **[31] Ryu GS, Kang ST, Park JJ, Koh GT.(2010)**The material attributes are understood by studying the stress strain behavior of UHPC cylinders under uniaxial compressive loading. The load –crack mouth opening displacement (cmod) of HPC beams, flexural strength and fracture energy was evaluated using third point loading test.The stressstrain characteristic shows that pre peak region has linear ascending portion and strain at peak stress increases with increase in strength and reinforcement index. The post peak curve is strongly dependent on the fiber type and fiber content and it is almost as steep as ascending curve for lower fiber contents and may be more gradually sloping for the higher fiber contents.**[32] Hamad BS, AbouHaidar EY(2011).**The effect of fibers was not observed in enhancing the pre-crack performance of the test specimens, whereas the ultimate bond strength and post peak bond strength performance increased significantly. The ultimate bond strength is found to be strongly affected by the compressive strength rather than fiber volume. Brittle failure was more pronounced in specimens with bigger sizes. The irregular post peak profile of load-slip curve resulting from this brittleness changed to smooth consistent one as the fiber dosage increased Fibers were found to influence both the ultimate bond strength and post maximum bond strength.**[33] Wille K, Naaman AE, Parra-Montesinos GJ.(2011).** Advances in the science of concrete materials have led to the development of a new class of cementations' composites, namely ultra-high performance concrete (HPC). The mechanical and durability properties of HPC make it an ideal candidate for use in developing new solutions to pressing concerns about highway infrastructure deterioration, repair, and replacementWhether used to facilitate accelerated construction, lengthen span ranges, or rehabilitate substandard infrastructure, UHPC can facilitate the development of unique solutions to existing challenges. As with any new material, utilization will grow as innovative applications are developed and market demand intensifies.**[34] El-Tawil S, Parra-Montesinos G.(2011)**The reported experimental program at the University of Illinois has been conducted to further understand the behavior of HPFRCC under general uniaxial and biaxial stress states, such as would be expected at various key locations in a coupling beam. In the future, completion of tension tests will further the understanding of the behavior of this sort of HPFRCC and provide more comprehensive knowledge about the material and its fully biaxial behavior. Such thorough understanding of HPFRCC has many implications, including making computer modeling and the extension of the material's use to more large-scale structural applications possible.**[35] X. K. Li, L. Sun, Y. Y. Zhou, S. B. Zhao, (2012)**Polypropylene Fiber Reinforced Concrete is an embryonic construction material which can be described as a concrete having high mechanical strength, Stiffness and durability. By utilization of Polypropylene fibers in concrete not only optimum utilization of materials is achieved but also the cost reduction is achieved.Polypropylene fibers reduce the water permeability, plastic, shrinkage and settlement and carbonation depth.Workability of concrete decreases with increase in polypropylene fiber volume fraction. However, Polypropylene fibers enhance the strength of concrete, without causing the well known

problems, normally associated with steel fibers.**[36] Corinaldesi V, Moriconi G.(2012**) The expected outcome which is the strength of hybrid fiber reinforced concrete is higher than the strength of normal concrete did achieved. So, further research need to be carried out with some adjustments of methods or materials.The rate of strength gain for 7 days strength of HFRC is very high as compared to conventional concrete and hence concludes that HFRC has high early Strength and continued strength development. As % of fiber increases the split tensile strength also increases. Workability drastically decreases when coconut fiber content is increased in concrete.**[37] Deeb R, Ghanbari A, Karihaloo BL.(2012)**the HSC mix to become a self-compacting mix will enable the inclusion of steel fibers without sacrificing its workability. In this study, the behavior of eight axially loaded medium scale columns cast with ultra-high-strength fiber-reinforced self-compacting concrete is investigated.At high fiber volume fraction the high deformability of the concrete activated the confinement exerted by the stirrups. d. For reducing the spacing between the stirrups did not significantly improve the confinement.**[38] Ramezanianpour, A.A. Esmaeili, M., Ghahari, S.A., and Najafi, M.H. (2013).**In this study Various mixture of class C fly ash in ratio of 30%, 40% and 50% was used in the concrete mix containing polypropylene fiber of volume fractions of 0.15,0.20,0.25,0.30 was used for all fly ash concrete mixes. Each series consists of cubes, cylinders and prisms as per IS standard.Compressive strength of concrete increases gradually by addition of Polypropylene fiber from 0.15% to 0.30%. There is increase in compressive strength as compared with normal plain concrete (without fibers) Splitting tensile strength of concrete increases gradually by addition of Polypropylene fiber from 0.15% to 0.30%. There is increase in splitting tensile strength as compared with normal plain concrete (without fibers).**[39] Tran TK, Kim DJ.(2014)**In this paper study of *M50 grade concrete* ... on cubes, cylinder and beams made of Quarry Dust with 5% *steel fiber*,and polymer 2.3% we have been using M50 Grade concrete for casting of segments Investigation is done on M30, and M50 mix using fly ash as partial replacement by weight of cement. Experimentation is carried out to find the compressive strength36.54 Mpa, flexural strength of the 14Mpa concrete blocks. Experimentation is also carried out analysis the production cost of concrete paving blocks by using Waste Material.

[40]Patel, P.A., Desai, A.K., Desai, A.J. (2015) Plain concrete has low tensile strength, less ductility, destructive and brittle failure. In order to improve these properties of plain concrete, an attempt has been made to study the effect of addition polypropylene fiber in ordinary Portland cement concrete. The addition of fibers into the concrete mixture marginally improves the compressive strength at 28 days but there is 51.05% increase in flexural strength with the addition of 0.25% fiber in concrete. It is observed from the experimental results and its analysis, that the compressive strength of concrete and flexural strength of concrete increases with addition of fibers.

[41] S. Kiruthika, Dr.G.S. Thirugnanam (2016).The effect of addition of mono fibres and hybrid fibres on the mechanical properties of concrete mixture made of M30 grade was studied in the

present investigation. In this study, the optimum addition of fibres obtained from previous reviews such as Steel fibres of 1% by volume of concrete and banana fibres of 0.5% by weight of cement was added individually to the concrete mixture as mono fibres and then they were added together to form a hybrid fibre reinforced concrete. Mechanical properties such as compressive 0.85 Mpa split tensile and flexural strength 0.92 were determined. The results show that hybrid fibers improve the compressive strength marginally as compared to mono fibers. Whereas, hybridization improves split tensile strength and flexural strength noticeably.

3.0 Results and discussions

References	**Year**	**Study**	**Results**
Qian, C.X Stroeven, P.[3]	**2000**	deals with the reinforcing efficiency of hybrid fibers	Maximum strength of concrete-increase 30%
Naaman, A.E **Reinhardt, H.W[5]**	**2001**	Developedforapplication as a transition layer of reinforced concrete.	The addition of microfibers to the steel fibres' increased the tensile stress in flexure and increased
Banthia, N.,Nandakumar, N.	**(2003)**	Use of different fiber as reinforcement in concrete for a greater durability, workability and reduction in crack.	FRC controls the micro cracking, shrinkage and deformation under load much better than plain concrete.
Lawler J, Zampini D, Shah S. Micro	**(2005)**	materials by the use of micro and macro fibers of different mechanical, geometrical and physical properties	Maximum load bearing capacity (peak load), residual flexural strength and flexural toughness unreinforced matrix are significantly increased
J.A.O. Barros, E. Pereira, A. Ribeiro , V. Cunha	**2005**	To study and technical details of the suggested technique along with those of the traditional sandwich panels are presented.	A large increase is observed of yield and ultimate load-carrying capacities of the proposed technique specimen compared to reference sandwich panel ones.

Kim DJ, El-Tawil S, Naaman AE	**(2007)**	the present work the strength studies are carried out to compare the glass and steel fiber concrete	The addition of Steel fiber the strength is increasing linearly, but in glass fiber up to 1% it is increasing and from 2% it is decreasing.
Patel, P.A., Desai, A.K., Desai, A.J.	**(2015)**	To study the effect of addition polypropylene fiber in ordinary Portland cement concrete.	Fibres improve the compressive strength and 51.05% increase in flexural strength.

Table-1 Comparison of mechanical properties of HFRC based on the different material compositions.

References	**Nomenclature**	**Grades**	**Cement (Kg)**	**water (Kg)**	**Coarse Aggregate (Kg)**	**Super plasticizers (Kg)**	**Compressive strength (Mpa)**	**Flexural strength (Mpa)**
Jungwirth J , 2008)	**HPC1**	**M40**	**515**	**150**	**1000**	**5.30**	**40.86**	**19**
Abou Haidar EY(2011)	**HPC2**	**M45**	**489**	**145**	**950**	**4.80**	**38.32**	**16**
H.W.,(2001)	**HPC3**	**M50**	**472**	**130**	**850**	**4.75**	**36.54**	**13**
Koh GT.(2010)	**HPC4**	**M55**	**443**	**125**	**760**	**3.80**	**44.51**	**11**
Desai, A.J. (2015)	**HPC5**	**M60**	**418**	**110**	**680**	**3.75**	**53.34**	**09**

Discussions:

- The results of the present investigation are presented in this section. Table 1 gives compressive strength of M40, M45, M50, M55 and M60 grades of concrete with various levels of replacement of cement by fly ash.
- For M60 grade of concrete, the compressive strength is increased when compared to normal concrete, replacement of cement.
- It can be stated that at M60of replacement of cement by fly ash, there is considerable increase in strength properties. Hence, M60 replacement can be considered as optimum replacement level to get enhanced strength. Also, it can be concluded that replacement of cement by fly ash is not suitable for higher grades of concrete such as M50. It results in decreased value of strength properties for the selected replacement levels of cement by fly ash.

4.0 CONCLUSIONS AND FUTURE SCOPE

- Fibres increasing the strengthening parameters, but the mix proportions variance have to be study for better optimistic results.
- Most of steel and glass fibres are researched to improve strengthening parameters like compressive and flexural strength.
- Polymer fibre increases strength approximately 50% with the addition of 0.25% as per the nearest work done.
- Hybrid fibres have to evaluate with different proportionate in a practical way to checkout for optimal results as future approaches.
- Finally concluded that most of the hybrid fibre mixes with HSC to check the durability applications for future enhancement.

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