International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 04 Issue: 07 | July -2017 www.irjet.net p-ISSN: 2395-0072

EXPERIMENTAL INVESTIGATION ON MECHANICAL PROPERTIES OF KEVLAR FIBRE

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Abstract

The experimental investigation was carried out on various types of fibres to find the use of the fiber in the structural engineering in particular and civil engineering in general. Various testing procedures were adopted to find the effectiveness and compatibility of fibre in concrete. In this paper the study was conducted about engineering and mechanical properties of Kevlar Fibre and in comparison with other fibers, testing of Kevlar fibre under various conditions and the very systematic comparative study was been carried out on the properties of Kevlar with respect to other fibers. The main objective of the study is to find out the mechanical properties and compatibility of fibre so that it can be used in concrete to enhance its properties and to increase its durability.

Keywords:- Tensile Strength, Ultimate Strength, Thermal Properties, Salts Attacks

1. INTRODUCTION

Although much of the research has been done to enhance the properties of concrete by various methods like by addition of Glass, coconut, Steel and by addition of some additives but not much research has been carried out by the use of kevlar fibre to check out the change in the mechanical properties of the Concrete. What made to think about this Kevlar Fibre? When this fibre is looked upon this fibre is an organic polymer which was invented by Chemist Stephanie in the year 1960's and was introduced in the year 1971 although it has numerous applications like in tyre Reinforcement, Bullet Proof Amours. This paper presents the current research on tensile properties, acid attacks, radiation attacks and the degradation of the fibre caused under elevated temperatures.

Chemical composition of Kevlar fiber

There are literally hundreds of synthetic plastics made by Polymerization (joining long chain Molecules) and they have widely different properties. Kevlar amazing properties are due to its internal structure and how its molecules are naturally arranged in regular and parallel lines and partly due to the way it is made in fibers by Knitting.

Chemical name for the Kevlar is

$C_{14}H_{14}N_2O_4$ Poly (p-pheylene terephthalamide)
Molecular Weight (274.276g/mol)

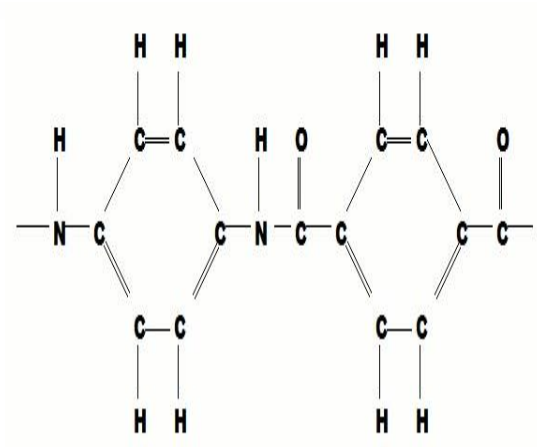

Fig.1 Chemical structure of Kevlar

2. EXPERIMENT INVESTIGATION

The Experiments of Testing were carried out Using UTM (Universal Testing machine) Humidity Chamber, furnace and the Fiber was subjected to many types of acid attacks For Min of 10

Hours and maximum of 1000 hours and The Degradation of the Fiber was noted.

Fig .2 Specimen of Kevlar fibre

3. RESULTS AND DISCUSSIONS

The Experimental Tests that were carried out and the following Results were revealed.

Tensile Properties

In this Table-1, the comparison was made between Kevlar 29 and Kevlar 49 based on strength test on yarn. The Criteria of comparison was tensile modulus which is relatively higher than that of the kevlar 29 and while checking out the other parameters of the fibre breaking tenacity in higher than that of the kevlar 29 and the rest values are sited in the table.

Table .1 Tensile Properties of Kevlar Fibre

Strength test on Yarn	Unit	Kevlar 29	Kevlar 49
Breaking Strength	N	338	264
Breaking Tenacity	MPa	2920	3000
Tensile Modulus	MPa	70500	112400
Elongation at Break	%	3.6	2.4
Resin impregnated Strands			
Tensile Strength	MPa	3600	3600
Tensile Modulus	MPa	83000	83000

By these results we conclude kevlar 49 is better than kevlar 29 and as such the kevlar 49 will show more compatibility if induced in concrete as concrete is weak in tension so the induction of such kind of fibre will enhance the tensile properties of concrete and for which the research is underway.

Yarn type

Table .2 Yarn Density

Property	Unit	Kevlar 29	Kevlar 49
Type	Filaments	1000	768
Density	g/cm^2	1.44	1.44
Moisture level As Shipped	%	7.0	3.5
Equilibrium From Bone Dry Yarn	%	4.5	3.5

In this table-2, we are comparing yarn type results for dampness of moisture between kevlar 29 and kevlar 49.kevlar 29 has attained more

Moisture which makes it inefficient to be used as a construction material as it will attain dampness at very early stage of the kevlar 49 will be the preferable material.

Thermal Coefficient of Kevlar

Table .3 Coefficient of thermal Expansion

COEFFICIENT OF THERMAL EXPANSION OF KEVLAR 29 AND 49			
Type of Kevlar	**Denier**	**Temperature Range (ºC)**	**Coefficient of Thermal Expansion**
Kevlar 29	1500	25-150	$-2.2 \times 10^6 - (-4.0 \times 10^6)$
Kevlar 49	1420	25-150	$-2.7 \times 10^6 - (-4.9 \times 10^6)$

In this Table-3, the results of thermal coeffiecients prove that kevlar 49 has more thermal expansion than kevlar 29 but the results which was deduce is that The 12.6×10^{-6} and that of Concrete is 14.5×10^{-6} which implies the fibre will induce very Low negative Shrinkage and will least develop cracks in Concrete.

Heat of Combustions of Kevlar

Table .4 Heat of Combustion of Kevlar

HEAT OF COMBUSTION OF KEVLAR 49 AND OTHER MATERIALS	
Material	**Heat of Combustion (J/Kg)**
Kevlar 49	34.4 X 10^6
Nylon Type 738	37.1 X 10^6
Nomex Aramid	30.8 X 10^6
Shell Epon	29.5 X10^6

In this table-4,out of the four results nylon type 738 has more heat of combustion and also kevlar 49 has second highest heat of combustion but the point that was deduced is that once the source of cumbustion is removed the fire stops instantaneoulsy.

Thermal Properties

Table .5 Thermal Properties of Kevlar

Property	Unit	Kevlar 29	Kevlar 49
Shrinkage			
In water at (100º)	%	<0.1	<0.1
In Dry Air at (177º)	%	<0.1	<0.1
Shrinkage Tension in Dry Air at (177º)	G.D	(0.88)	(1.77)
Specific Heat			
At (25º)	J/kg C	1420	1420
At (100º)	J/kg C	2010	2010
At(180º)	J/kg C	2515	2515
Thermal Conductivity	W (m K)	0.04	0.04
Decomposition Temperature in Air	ºC	(427-482)	(427-482)
Recommended Max Temperature Range for Long Term Use in Air	ºC	(149-177)	(149-177)
Heat of Combustion	Joules Kg	(35 X 10^6)	(35 X 10^6)
Poisson Ratio	-		0.36

In this table .5, from the above results we prove that every property is same except
Kevlar 49 has higher shrinkage than kevlar 29 and it has poisson ratio of 0.36 by these results proved that kevlar 49 is better than kevlar 29 and hence the kevlar 49 qualifies in the properties and can be used as construction material in a larger scale as it can cause least crack development in concrete.

Properties of Kevlar in Comparison to Other Fibres

Table .6 Comparison of Kevlar with other fibers

Kevlar	Specific Density Lb/in^3	Tenacity 10^3	Modulus 10^6	Break Elongation	Specific Tensile Strength 10^6	CTE 10^{-6} /ºF	Decomposition Temperature ºF	ºC
Kevlar								
Kevlar 29	0.052	424	10.2	3.6	8.15	-2.2	800-900	(427-482)
Kevlar 49	0.052	435	16.3	2.4	8.37	-2.7	800-900	(427-482)
Other yarn								
S-Glass	0.090	665	12.4	5.4	7.40	1.7	1562	850
E-Glass	0.092	500	10.5	4.8	5.43	1.6	1346	730
Steel Wire	0.280	285	29	2.0	1.0	3.7	2732	1500
Nylon-66	0.042	143	0.8	18.3	3.40	-	490	254
Polyester	0.050	168	2.0	14.5	3.36	-	493	256
HS Polyethylene	0.035	375	17	3.5	10.7	-	300	149
High Tenacity Cartoon	0.065	450	32	1.4	6.93	-0.1	6332	3500

The results that were drawn from the above table it can be observed that the kevlar 29 and kevlar 49 has the decomposition temperature of around (427-482), specific tensile strength of kevlar 49 is 8.37 X 10^6 and which is very much higher when compared to that of the provided in the table.

Testing of Kevlar under Salt attacks

Table .7 Effect of Kevlar under salt solution attack

Chemical	Concentration (%)	Temperature (ºC)	Time (Hr)	Effects on Breaking Strength
Salt Solution				
Copper Sulphate	3	21	1000	None
Copper Sulphate	3	99	100	Moderate
Ferric Chloride	3	99	100	Appreciable
Sodium Chloride	3	21	1000	None
Sodium Chloride	3	99	100	None
Sodium Chloride	10	121	100	Appreciable
Sodium Phosphate	5	99	100	Moderate

The fibre was tested under various salt solutions of varied concentration such as Sodium Cholride, Sodium Phosphate and to copper sulplate From the above kevlar has proved better to the acids attacks with various concentration, temperature, time, and the effect on breaking strength of Kevlar was almost negligible .it is best resistible to sodium chloride attacks. Since it is resistant to the salts attack which imples it can be used in the foundation material as well to enhance properties of concrete.

Testing Of Kevlar under Ocean Waters

Table .8 Effect of Kevlar under different waters

Chemical	Concentration (%)	Temperature (ºC)	Time (Hr)	Effects on Breaking Strength
Salt				
Water (Salt)	5	21	24	None
Water (Tap)	100	21	24	None
Water (Tap)	100	100	100	None
Water	100	99	100	None
Water (Ocean)	100	121	1 year	None

In this test the kevlar was kept under different set of waters and the effect of different waters was noted on the fibre.The fibre was kept as minimum as 24 hours and to the maximum of 1 year under the water.it was noted that there was any kind of degradation found in the fibre which makes this fibre apt for offshore construction.

Testing of Kevlar under Oil various Oils

Table .9 Effect of Kevlar under various types of oils

Chemical	Concentration (%)	Temperature (ºC)	Time (Hr)	Effects on Breaking Strength
Jet Fuel	100	21	24	None
Kerosene	100	60	600	None
Suva	100	21	1000	None
Gasoline	100	21	1000	None
Gasoline	100	21	24	None

The of fibre was keenly observed when the noted.it was observed that such prolonged experimentation under various type of oils showed that the effect of oils on the fibre was negligible.hence the fibre when mixed with concrete can be used in construction of storage tanks and silos.

Testing of Kevlar under UV Protection

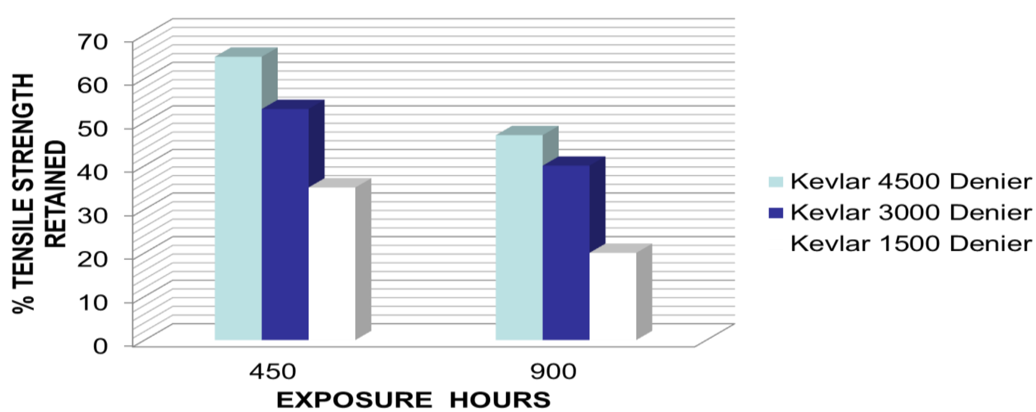

Fig.3 Percentage Tensile strength Retained on Exposure

From the above graph on comparing both exposure hours versus tensile strength retained for both the hours' tensile strength retained is high for kevlar 4500 denier(denier are number of filaments per bundle of fibre) in but with exposure time 450 hours kevlar 4500 has more tensile strength retained than 900 hours and the performance showed by the kevlar is good and can be used in the lining of nuclear reactors.

MOISTURE REGAIN

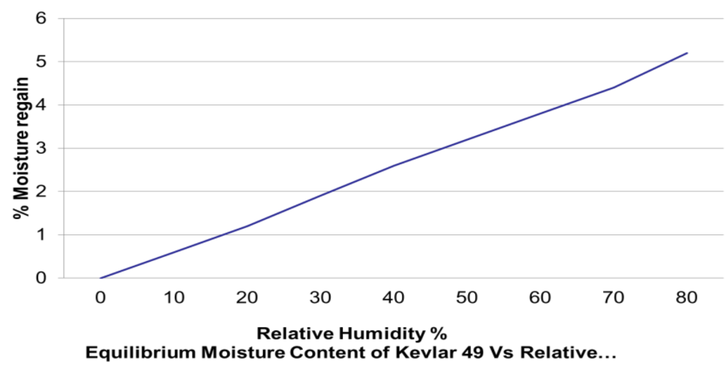

Fig .4 Absorption of Moisture

The above graph shows the kevlar 49 regains moisture with time. More the relative humidity more wills the moisture retained in the kevlar fiber. This may be considered as the bad advantage but regain of moisture may cause dampness in the structure.

CONCLUSION

The Experimental Investigation that was carried so far on various types of fibers proved that

- **Kevlar of grade 49** Performed best and Hence Same will be inducted in concrete to see the change in the Mechanical Properties.
- It is strong but relatively light, the specific tensile strength of both K29 and K49 is 8 times Greater than that of steel.
- Unlike most plastics it doesn't melt, it can with stand the temperature of 450ºC (800ºF).
- Kevlar can get ignited but the burning usually stops when the heat source is removed.
- Even at very low Temperatures the Kevlar doesn't get effected established research concluded that Kevlar can withstand the temperature of down to -196ºC (-320ºF).
- Kevlar can withstand the attack of acids but interaction with strong acids can result in discoloration and degradation of the Kevlar.
- Research has established that after exposure to hot water for 200 days the properties of the fiber remains unaffected.
- The Kevlar can survive in Sea water as well.

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