Studies on Furan Polymer Concrete

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Abstract - *Polymer concretes are composite materials made of polymeric binder along with filler materials, and have excellent strength, high density and durability property along with the resistance towards chemicals. Polymer concrete mineral filler content may reach up to 95% by weight. Using different sizes of filler and poly furfuryl alcohol resin based binder; a series of polymer concrete of different composition was prepared. For each composition, compressive strength was checked in UTM. The effect of quantity of binder, curing agent and size of fillers on compressive strength of concrete is discussed. In this work the binding material used is poly furfuryl alcohol, which is a thermally cross linked polymer that is synthesized from furfuryl alcohol monomer. Further FTIR analysis is done to study the polymerization of furfuryl alcohol.*

Keywords: **Filler, FTIR, Polymer Concrete, Resin, UTM**

1. INTRODUCTION

The current standard building material, namely Portland cement concrete prepared by binding aggregate with Portland cement, has a number of deficiencies which make it inappropriate for some application. For instance, a suitable cure with Portland cement takes approximately 28 days. In addition, chemical resistance to acid is lacking in Portland cement. Several attempts have been made to replace Portland cement with different building material compositions to overcome the above described problems. Such substitute materials will compromise on one property such as strength for another property such as acid resistance or the like. These substitutes have taken the form of both coating and lining for Portland cement as well as complete replacement materials. Polymer concrete is a composite material in which the aggregates are bound together in a polymer matrix. The composite do not contain any Portland cement component. Application and performance of polymer concrete is dependent upon the specific polymer binder as well as the type of aggregates and its gradation. The distribution of aggregates should be such as to allow for a minimum void volume for dry packed aggregates which will result in dense packing. Dense packing of aggregate in the polymer concrete matrix results in better properties. To achieve this, either the void content of the aggregate mix can be minimized where the binder requirement for ensuring adequate bonding of all aggregate particles will be less or use loosely packed aggregate with higher binder content [1]. Though the aggregate and micro filler form a major component of total mass of the polymer concrete, there has not been much emphasis on the aggregate and micro filler mix proportion used in such system. The aggregates used in polymer concrete are either fine particles or the particle size distribution chosen are based on theoretical basis suitable for Portland cement concretes. Also the effect of aggregate mix proportion on void content and method of optimizing mix proportion to have minimum void content has been reported [2,3]. Furan resin offer several advantages over other synthetic resin based binder system such as unsaturated polyester, epoxy etc. The major raw material used in the synthesis of furan polymer is furfuryl alcohol and furfuraldehyde which are obtained from agricultural wastes. Condensation product of furfuraldehyde and acetone in different mole ratio are more commonly used, even though other types of furan resin such as homopolymer of furfuryl alcohol or a copolymer of furfuryl alcohol and furfuraldehyde are also known to be good binder for chemical resistance application. Furan resins can be cured through heat or by addition of a chemical agent [4,5].

2. EXPERIMENTAL WORK

2.1 Preparation of furan resin

For manufacturing furan resin at lab level, furfuryl alcohol of Merck chemical company was used. In the process 45ml furfuryl alcohol and 1ml of O- Phosphoric acid was taken in round bottom two neck flask in which thermometer and stirrer was fitted. Flask was heated on heating mantle at continuous rate with stirring. When the temperature of reaction mixture reached between 95 to 100°C, a sudden evolution of heat was observed and this was the point of actual reaction. Heat of the exotherm was controlled to prevent premature cross linking. The evolution of heat was successfully controlled to get furan resin of glowing colour with viscosity of about 250 cP and pH of resin was maintained between 5 and 6 by adding 1 ml of tri ethanol amine.

2.2 Analysis of furan resin by FTIR analysis

In Fourier transform infrared test, the infrared radiation is passed through sample. Some of IR radiation is absorbed by the sample. FTIR is used to get the functional group in given sample. Chart 1 show FTIR spectra of furan resin which was obtained by transmittance technique at ambient temperature of 20°C. The $-CH_2-$ bend comes at 1465 cm^{-1}, C=C (aromatic) stretch comes at 1600-1475 cm^{-1} and etheric comes at 1300-1000 cm^{-1}. From the spectra given of chart 1, the present stretches show the presence of functional group and bonds in prepared furan resin sample.

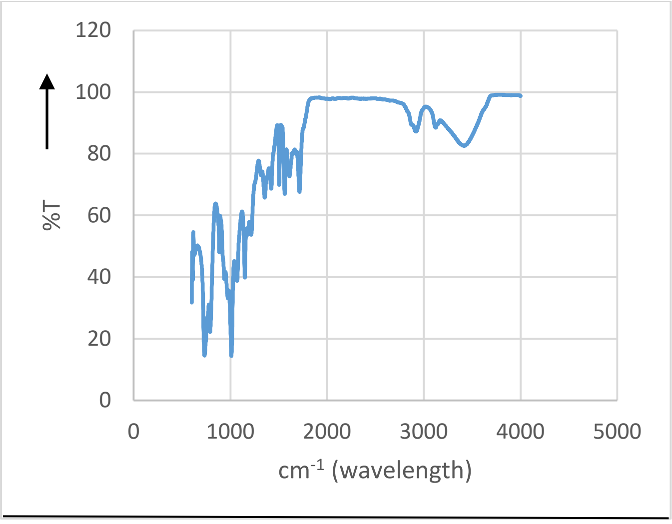

Chart -1: % of transmittance versus wavelength

2.3 Preparation of aggregate

After the collection of required quality sand, it was washed out in clean lab glass wares and subsequently dried. To remove the moisture content, sand was heated in hot air oven at 120°C for about 4 hours. When the moisture was completely removed, sieve analysis was performed. Sieves used for grading sand were of size 180 µm, 210 µm, 355µm and 420µm.

2.4 Preparation of polymer concrete

Polymer concrete of different composition was prepared by mixing required quantities of resin with additive, aggregate, micro filler and catalyst. Initially aggregate, micro filler and catalyst were mixed in a powder mixer. Additive was added to resin separately and homogenized. Into this homogeneous viscous mass, the premixed material (of aggregates, catalyst and micro filler) was added slowly while stirring at slow speed to ensure that no air bubbles are trapped in the prepared polymer concrete mortar. After complete mixing, the prepared polymer concrete was casted in split type cylindrical mould of 43.4 mm height and 23.1 mm diameter. Specimen was removed after six to seven hours and the compressive strength of the specimen was tested in universal testing machine.

3. RESULTS AND DISCUSSION

3.1 Effect of aggregates on concrete strength

To estimate the effect of particle size of coarse aggregates on compressive strength of the concrete, the amount of curing agent (tri chloro toluene) was kept 0.25 gm, promoter (aniline hydrochloride) 2.5 gm and the quantity of resin kept at 4 gm. Table 3.1 gives the effect of particle size on compressive strength. Load versus displacement pattern of different particle size coarse aggregates are shown in chart 2 to 4. Compressive strength of 420-355 μm particle size is 3.213 MPa, 355-210 μm particle size is 5.051 MPa and 210-180 μm particle size is 6.274 MPa.

Table -3.1: Effect of particle size on compressive strength

Sr. No.	Particle size of sand (μm)	Compressive strength (MPa)	Peak load (KN)
1	420-355	3.213	1.347
2	355-210	5.051	2.118
3	210-180	6.274	2.630

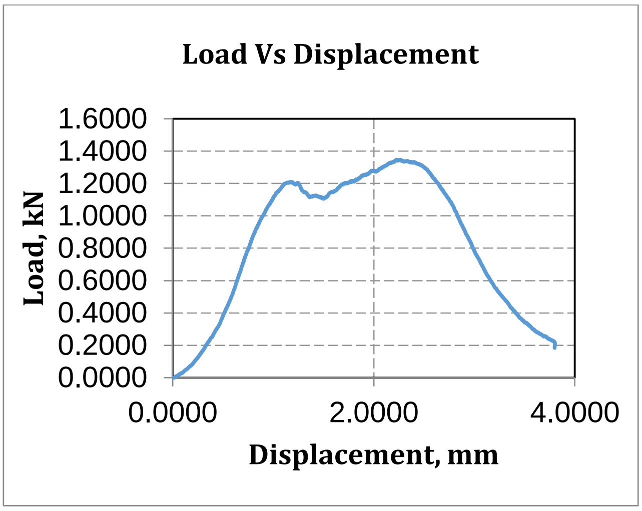

Chart -2: Concrete with 420-355 µm size aggregates

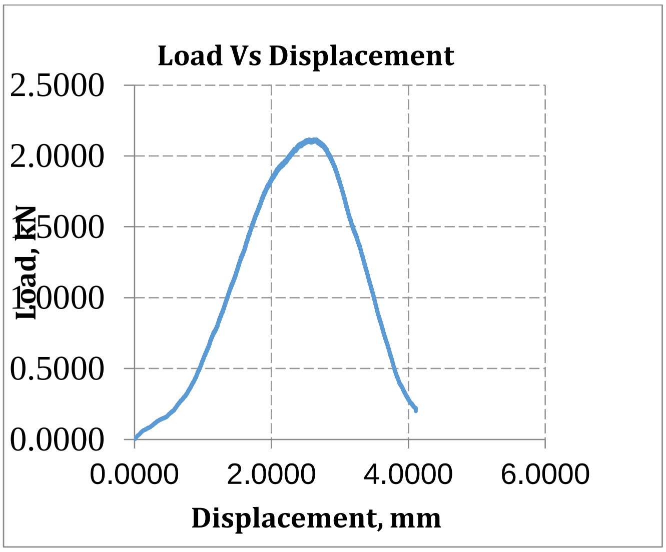

Chart -3: Concrete with 355-210 μm size aggregates

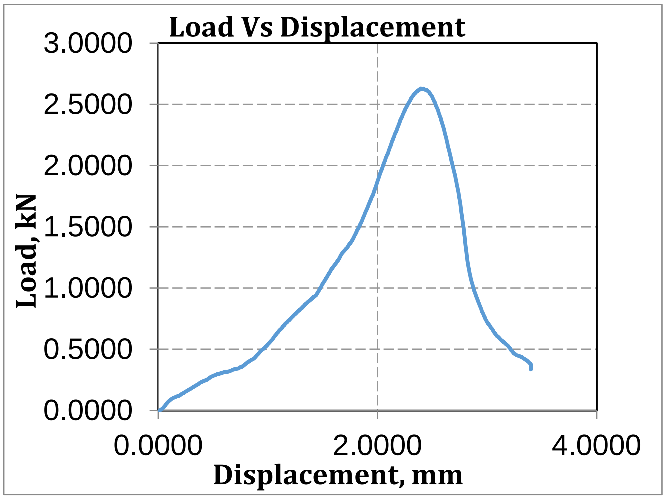

Chart -4: Concrete with 210-180 μm size aggregates

3.2 Effect of micro filler on concrete strength

Micro fillers like calcium carbonate, micro silica, quartz powder can be used. Table 3.2 gives the effect of micro filler on compressive strength in three different samples in which quartz powder of 75 microns and sand of 355-210 microns is used and the mass of resin, TCT and promoter are kept constant to 4 gm, 0.25 gm and 2.5 gm respectively. Load versus displacement pattern are shown in charts 5, 6 and 7 with different combinations of coarse aggregates and micro filler. Compressive strengths of three samples when 30 gm sand without micro filler, 25 gm sand and 5 gm micro filler, 20 gm sand and 10 gm micro filler were used, are 5.051 MPa, 6.122 MPa and 8.157 MPa respectively.

Table -3.2: Effect of micro filler on compressive strength

Sr. No.	Micro filler and sand (gm)	Compressive strength (MPa)	Peak Load (KN)
1	00 and 30	5.051	2.118
2	05 and 25	6.122	2.567
3	10 and 20	8.157	3.420

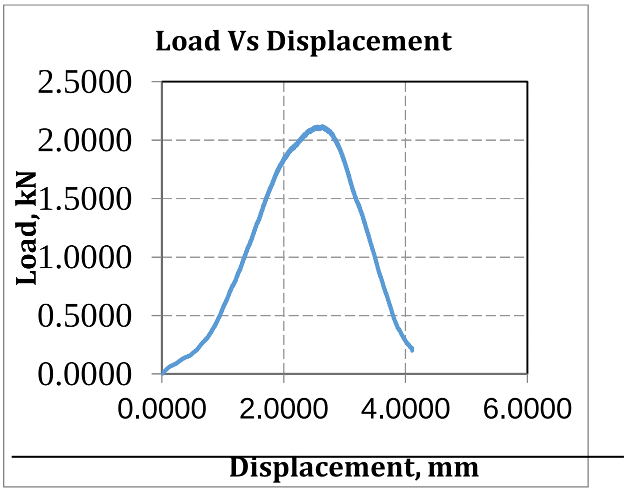

Chart- 5: Concrete with 30 gm sand and no micro filler.

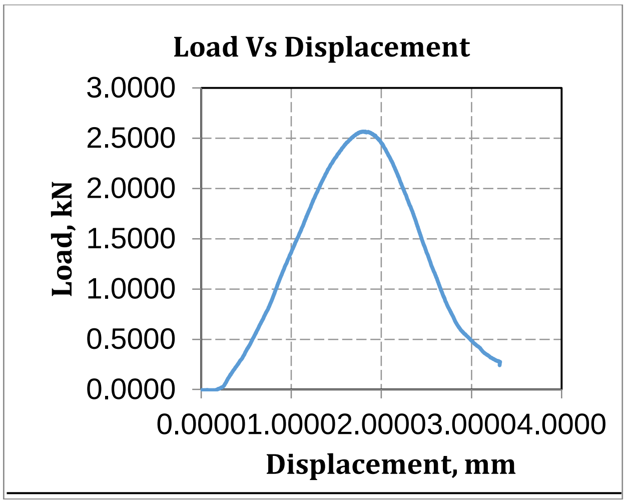

Chart -6: Concrete with 25 gm sand and 5 gm micro filler.

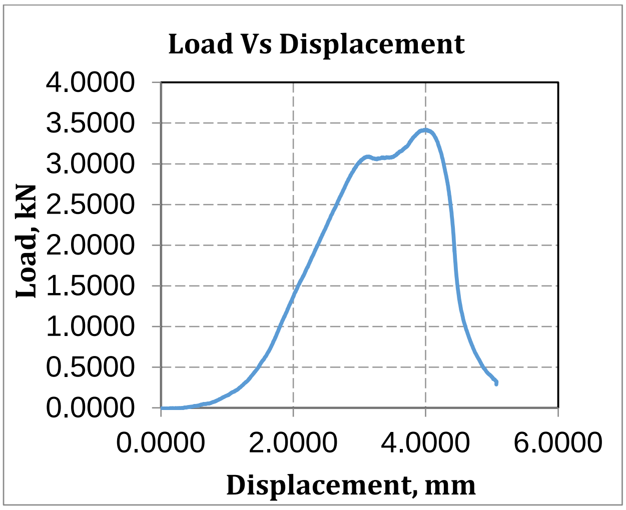

Chart -7: Concrete with 20 gm sand and 10 gm micro filler.

3.3 Effect of Promoter

Promoter increases the activity of catalyst. Aniline hydrochloride was utilized as promoter in the preparation of polymer concrete. To study the effect of promoter, mass of resin, sand (with particle size 210-180 µm), TCT was kept constant to 4 gram, 30 gram and 0.25 gram respectively. Table 3.3 is showing the effect of promoter on the strength of polymer concrete prepared.

Table -3.3: Effect of promoter on compressive strength

Sr. No.	Aniline hydrochloride	Compressive strength (MPa)	Peak load (KN)
1	0.0	5.406	2.267
2	1.0	5.963	2.5
3	2.5	6.123	2.567

Load versus displacement chart of three samples processed with varying quantity of promoter have been shown in charts 8, 9 and 10 respectively. Compressive strengths of the three samples, which are, without promoter, with 1.0 gram promoter and with 2.5 gram promoter are 5.406 , 5.963 , 6.123 MPa respectively.

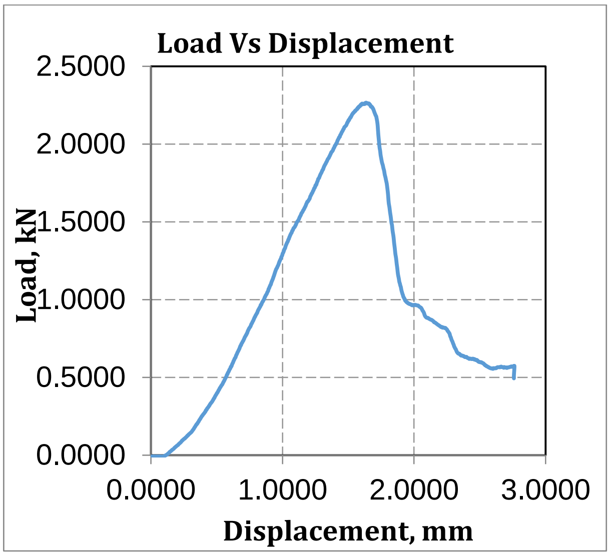

Chart -8: Polymer concrete processed without promoter.

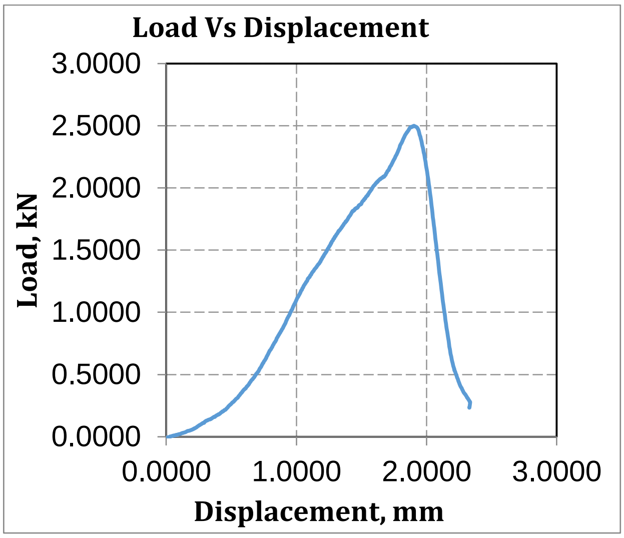

Chart- 9: Concrete processed with 1 gm promoter Strength

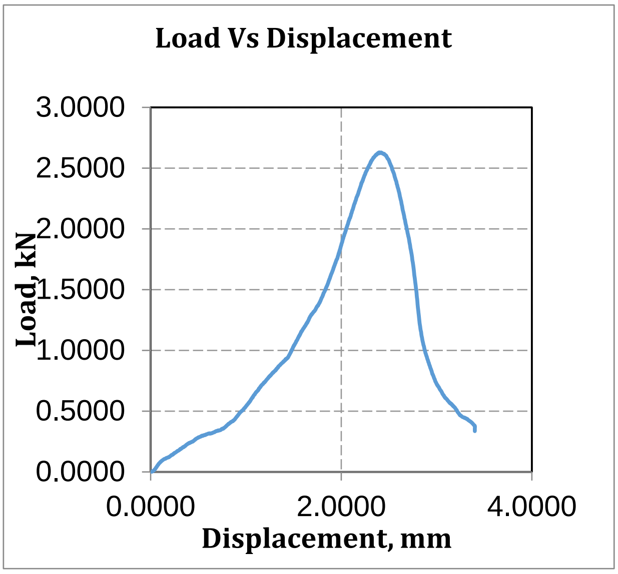

Chart- 10: Concrete processed with 2.5 gm promote

3.4 Effect of curing agent on compressive Strength

To observe the effect of curing agent on compressive strength, the amount of resin was kept 4 gm, promoter (aniline hydro chloride) to 2.5 gm and 30 gm sand (particle size 210-180 μm) was taken in both the samples which were prepared. The amount TCT was varied from 0.25 gram to 0.75 gram. Table 3.4 is showing the effect of curing agent on the strength of polymer concrete prepared.

Table -3.4: Effect of curing agent on compressive Strength

Sr. No.	TCT (gm)	Compressive strength (MPa)	Peak load (KN)
1	0.25	6.2474	2.630
2	0.75	7.257	3.049

Load versus displacement pattern for different mass of curing agent used, have been shown in charts 11, 12 respectively. Compressive strength of two samples in which 0.25 gm and 0.75 gm curing agent was utilized is 6.2474 MPa and 7.257 MPa respectively. Curing agent is responsible for the cross-linking in the polymer and ultimately affects the compressive strength and setting time. As per application and desired characteristic of the concrete, it can be optimized,

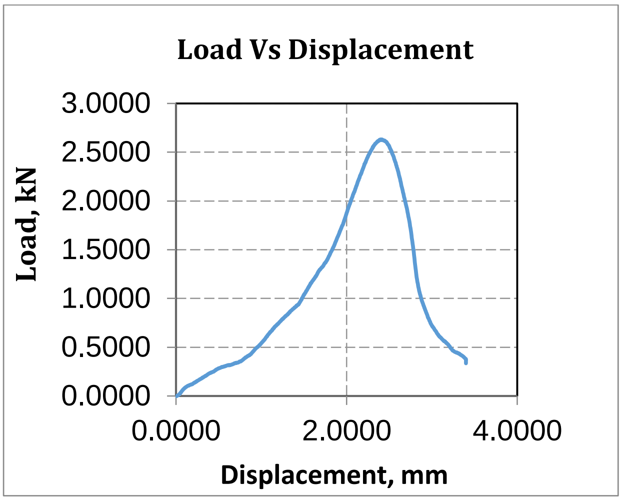

Chart -11: Concrete with 0.25 gm curing agent

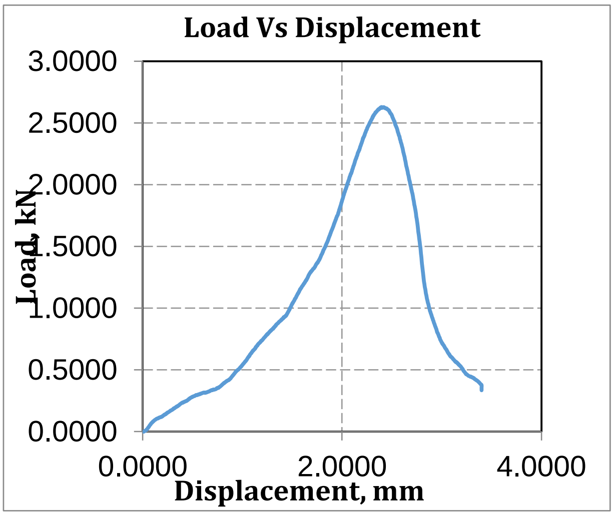

Chart -12: Concrete with 0.75 gm curing agent

3.5 Effect of resin on compressive strength

To observe the effect of resin on compressive strength, amount of TCT was kept 0.25 gm and promoter (aniline hydro chloride) 2.5 gm. Amount of resin was varied with 210-180μm particle size filler. Table 3.5 is showing the effect of resin on the strength of polymer concrete prepared.

Table -3.5: Effect of resin on compressive strength

Sr. No.	Resin (gm)	Compressive strength (MPa)	Peak load (KN)
1	1.0	1.110	0.466
2	4.0	6.2474	2.63
3	6.0	11.099	4.613

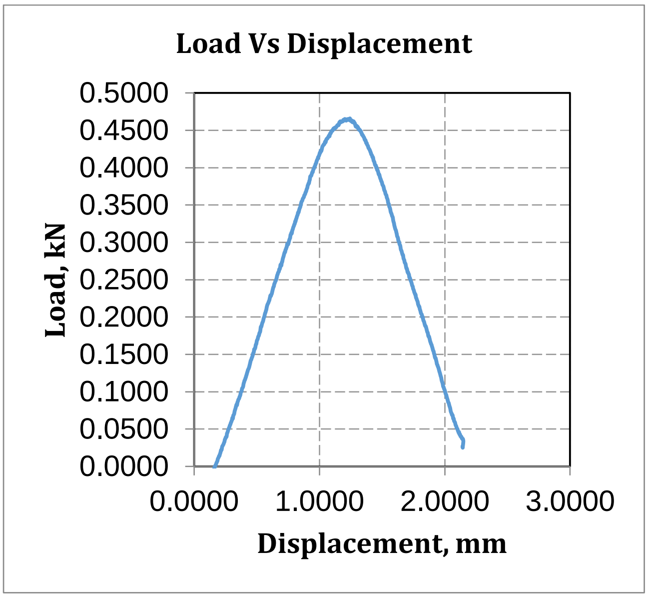

Chart- 13: Concrete with 1 gm resin

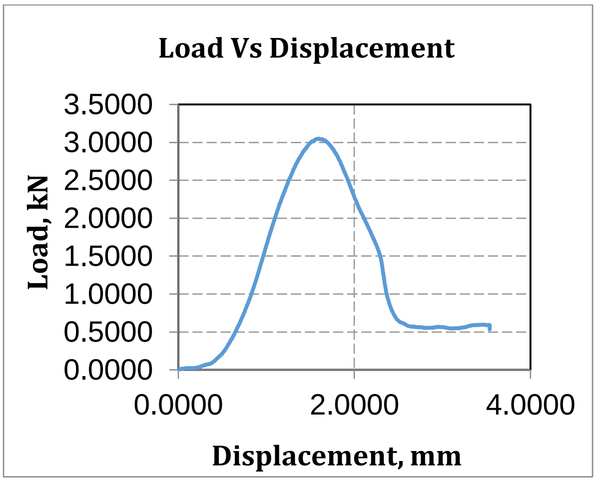

Chart- 14: Concrete with 4 gm resin

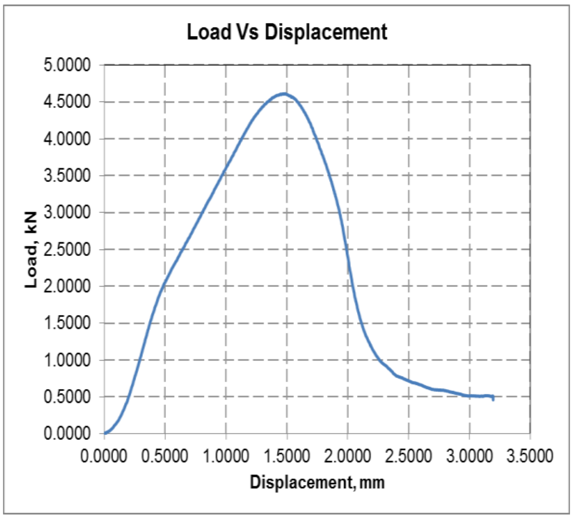

Chart- 15: Concrete with 6 gm resin.

Load versus displacement pattern of concrete with different mass of resin is shown in chart 13, 14, 15 respectively. Compressive strength of three samples in which 1.0 gm, 4 gm and 6 gm resin was taken is 1.110 MPa, 6.2474 MPa, and 11.099 MPa respectively.

3.6 Cement Concrete

To compare the compressive strength of polymer concrete with cement concrete two samples of cement concrete were prepared utilizing Birla ultimate cement. First sample was prepared with cement, sand and red sand in ratio of 1:1:2 by mass, respectively. Size of sand particles were between 420-355 μm and that of red sand particles were in range of 1003-710 μm, with setting allowed for 30 days. Compressive strength of the sample prepared was found to be 2.759 MPa and load versus displacement pattern is shown in chart 16. Second sample was prepared with cement, sand and red sand in ratio 1:2:2 by mass respectively. Particle size and specimen setting period were kept same. Compressive strength of the sample processed was estimated to be 0.717 MPa and load versus displacement pattern is shown in chart 17.

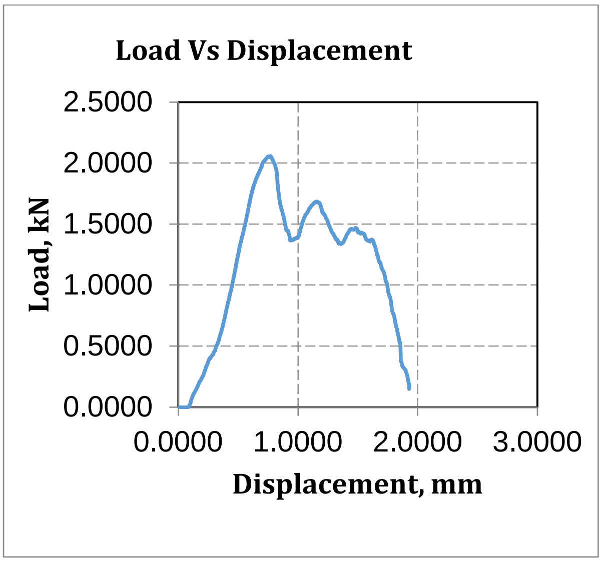

Chart -16: Cement concrete specimen I

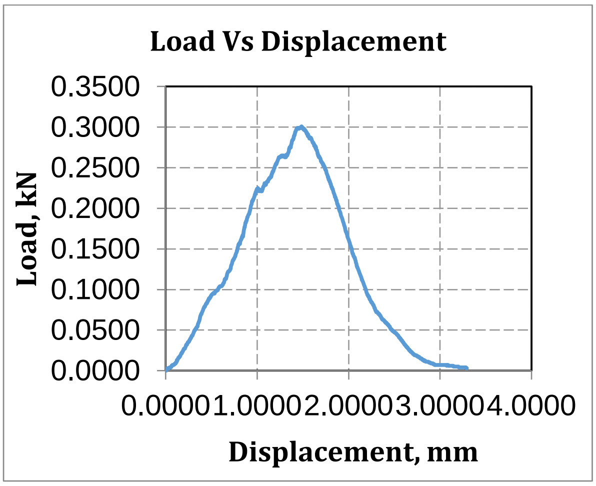

Chart-17: Cement concrete specimen II

4. CONCLUSION

In this study furfuryl alcohol has been used as binder for concrete. The use of polymer resin binder, instead of cement gives stronger concrete with good chemical resistance and quick setting properties. These characteristics decide the application of this concrete at places where these characteristics are desired. Compressive strength of polymer concrete can be increased by reducing void content by using micro filler. Quantity of resin, aggregate type and quantity, curing agent as well as promoter play critical role in the strength properties of the polymer concrete. Concrete based on poly furfuryl alcohol resin show higher compressive strength and load bearing capacity in comparison to cement concrete. Thus in process industries and in other areas where chemical resistance, quick setting time and specific compressive strength is desired, the polymer concrete finds definite application.

References

[1] Muthukumar, M., and Mohan, D., "Studies on polymer concretes based on optimized aggregate mix proportion". European Polymer Journal. Vol. 40, 2004, 2167-2177.
[2] Fowler, D., W., "Polymer in concrete: a vision for the 21st century". Journal of Cement Concrete Composites, Vol.21, 1999, 449-452.
[3] Muthukumar, M., and Mohan, D., "Studies on furan polymer concretes". Journal of Polymer Research. Vol. 12, 2005, 231-241.
[4] Bobrowski, A., and Grabowska, B., "The impact of temperature on furan resin and binder structure". Metallurgy and Foundry Engineering, Vol. 38(1), 2012, 73-80.
[5] Krishnan, T., A., and Chanda, M., "Kinetics of polymerisation of furfuryl alcohol in aqueous solution". Die Angewandte Makromolekulare Chemie, Vol. 43, 1975, 145-156.
[6] Gandini, A., and Belgacem, N., M., "Furan in polymer chemistry". Prog. Polym. Sci.,Vol. 22, 1997, 1203-1379.
[7] Wang, H., and Yao, J., "Use of polyfurfuryl alcohol in the fabrication of nanostructured carbons and nanocomposites". Ind. Eng. Chem. Res., Vol.45, 2006, 6393-6404.