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THERMAL CHARACTERIZATION OF POLYMER CONCRETE FROM UNSATURATED POLYESTER RESIN REINFORCED WITH WHITE SAND

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ABSTRACT

Polymer concrete as a building material can benefit construction industry in maintaining its economy. Thermal properties are important material properties for engineering applications. Analysis of prepared polymer concrete is an important issue for a composite of unsaturated polyester resin and white sand. The main purpose of this research is to prepare polymer concrete having high performance and standard thermal properties. Thermal properties such as thermal conductivity, thermo-mechanical properties and thermo-gravimetric properties have been studied of prepared polymer concrete at various compositions. Collection of raw materials, washing of white sand, purchasing of unsaturated polyester resin and methyl ethyl ketone peroxide, weighing, mixing and molding have been done. Prepared polymer concrete has been sectioned around 10mmx10mm cross-sectional area and cleaning has been done after sectioning. After cleaning; prepared polymer concretes have been set to TMA and TGA respectively for obtaining graph in the computer. Thermal conductivity of prepared polymer concrete has been measured by Lee's and Charlton's method. Thermal conductivity of prepared polymer concrete decreases with increasing of white sand. Linear average co-efficient of thermal expansion is the outcome of thermo-mechanical analysis. Linear average co-efficient of thermal expansion of prepared polymer concrete decreases with increasing of white sand. The maximum degradation rate is 1.574 mg/min that has been found for prepared polymer concrete without white sand. The maximum degradation rate of prepared polymer concrete containing 50% and 60% white sand have been increased slowly.

Keywords: *Thermal conductivity, TMA, TGA, The Rate of Degradation*

1. INTRODUCTION

Polymer concrete is a composite material which results from polymerization of a monomer/aggregate mixture. The polymerized monomer acts as binder for the aggregates and the resulting composite is called "Concrete". Polymer concrete in which the binder is an organic polymer; a construction and structural material that is a solidified mixture of a macro molecular substance with a mineral aggregate.[1-2] Polymer and polymer-cement concretes are used for floors in industrial plants, garages, and hospitals. They are used in the production of high-quality road and air field paving' sand for repairing damaged concrete surfaces and patching cracks. The overall goal of this research work has to investigate some thermal properties of prepared polymer concrete from unsaturated polyester resin reinforced with white sand. In order to study the possibility of superior performance, preventing the composite from extreme heat; polymer

concrete has been prepared with different compositions. In view of the above consideration, the following work- plans have been undertaken: collection of raw materials, preparation of polymer concrete with different compositions from unsaturated polyester resin and white sand, determination of thermal properties such as thermal conductivity, thermo-mechanical analysis (TMA) and thermo-gravimetric analysis (TGA) of prepared polymer concrete. The main objectives of this research work are:

i) Preparation of high- performance polymer concrete for construction purposes.
ii) Preparation of polymer concrete with standard thermal properties.

The thermal behaviors of prepared polymer concrete have been analyzed to correlate the structure- property relation. This research work gives the ideas to find a suitable composite for the application in the field of construction.

2. MATERIALS AND METHODS

2.1 Materials

Polymer concrete formulation has been prepared by mixing white sand and unsaturated polyester resin. White sand content in polymer concrete has been varied from 20% to 60% in the polymer concrete formulation. Methyl ethyl ketone peroxide (MEKP) is an organic, colorless and oily liquid which has been used as hardener in the polymer formulation. Methyl ethyl ketone peroxide (MEKP) has been used as 1% of unsaturated polyester resin in the polymer concrete formulation.

2.2 Equipments

The equipments have been used here, such as Slide-calipers, Screw gauge, Huber-thermal conductivity analyzer, Thermo-gravimetric analyzer and Thermo-mechanical analyzer.

2.3 Methods

2.3.1 Collection of Raw Materials

Firstly, for the preparation of polymer concrete, the basic raw materials are white sand; unsaturated polyester resin and methyl ethyl ketone peroxide have been purchased. To prepare polymer concrete from these raw materials following steps are involved:-

- ✓ Washing of white sand and purchasing of unsaturated polyester resin and methyl ethyl ketone peroxide from the market.
- ✓ Weighing
- ✓ Mixing
- ✓ Molding

2.3.2 Method of Thermo-Gravimetric Analysis (TGA) Measurement

Thermo-gravimetric analysis or thermal gravimetric analysis (TGA) is a method of thermal analysis in which changes in physical and chemical properties of materials are measured as a function of increasing temperature (with constant heating rate), or as a function of time (with constant temperature and/or constant mass loss). TGA can provide information about physical phenomena, such as second-order phase transitions, including vaporization, sublimation,

absorption, adsorption, and desorption.[3-4] The prepared polymer concrete has been sectioned and around 10mmx10mm cross-sectional area has been prepared. Cleaning of prepared polymer concretes have been done after sectioning prepared polymer concrete. After then polymer concretes have been set to TGA for obtaining graph in the computer. The obtaining graph has been analyzed in that computer of the TGA.

2.3.3 Method of Thermo-Mechanical Analysis (TMA) Measurement

Thermo-mechanical analysis (TMA) is a technique used in thermal analysis, a branch of materials science which studies the properties of materials as they change with temperature. Thermo-mechanometry is the measurement of a change of a dimension or a mechanical property of the sample while it is subjected to a temperature regime. The prepared polymer concrete has been sectioned and around 10mmx10mm cross-sectional area has been prepared. Cleaning of prepared polymer concretes has been done after sectioning. After then polymer concretes have been set to TMA for obtaining graph in the computer. The obtaining graph has been analyzed in that computer of the TMA (Wellisch E. et. al., 1961 & Farahany et.al., 2012).

2.3.4 Method of Thermal Conductivity Measurement

According to the ASTM method C 201 the thermal conductivity can be measured. But an alternative method for the test of thermal conductivity is Lee's and Charlton's method. The method is described as follows: The thermal conductivity of a bad conductor or sample like rubber, ebonite, glass, refractory, concrete etc. can be measured by this method. In measuring the conductivity of such poor conductors or samples, a thin layer or slab of the material or sample is used. The difficulty arises in maintaining the face at uniform temperature and in measuring that temperature. Lee's and Charlton's method has overcome this difficulty by placing a good conductor such as brass or copper, of exactly the same diameter as the experimental slab on each side of the poor conductor or sample. In this method two metal discs are used and a poor conductor or sample is placed between two that metal discs. [7-8] there is an oil chamber from where heat is produced. Heat passes to the upper metal disc and then flows through poor conductor or sample to the bottom metal disc. When heat is passed through the upper disc, the poor conductor or sample is warmed. When the rate of flow of heat through the sample equals the heat loss from the upper disc by radiation and convection then steady state will be reached (Rao V. V. L. K. et. al., 1993 & Chmielewska B. et. al., 2006). If

$T_{1=}$temperature of the upper disc in the steady state
$T_{2=}$ temperature of the bottom disc in the steady state
$A_{=}$ Cross-sectional area of the sample
K= thermal conductivity of the sample
d = thickness of the sample
Then the quantity of heat conducted per second through the sample is

$$Q=KA\ (T_1-T_2)/d$$

In the steady state this heat Q is radiated per second from A. if m and S be the mass and specific heat of A and dT/dt be its cooling rate at temperature T_2, the heat loss (radiated per second) from A is,
Q= ms (dT/dt)

dT/dt is determined by performing s subsidiary experiment. From the above equations the thermal conductivity of the sample is

$$K = ms\,(dT/dt)\,d / A\,(T_1 - T_2)$$

The weight, diameter and thickness of the sample have been measured with a balance and a slide calipers respectively. Then the sample has been polished by polishing paper for good contact. The oil chamber generates heat. The temperature T_1 and T_2 has been noted at an interval of one minute until they remain steady, for at few consecutive readings for several minutes. Then heat supply has been stopped and the upper disc has been removed. [9-10] with the slab, the sample is still on the top, the bottom disc has been heated to a temperature of (T_2 $+20^0$C).Then the bottom disc has been allowed to cool. By keeping the sample on the bottom disc, it has been ensured that the heat lost to the surrounding is the same as in the first part the experiment when it has gained heat. The cooling time has been measured for decreasing temperature in every minute.

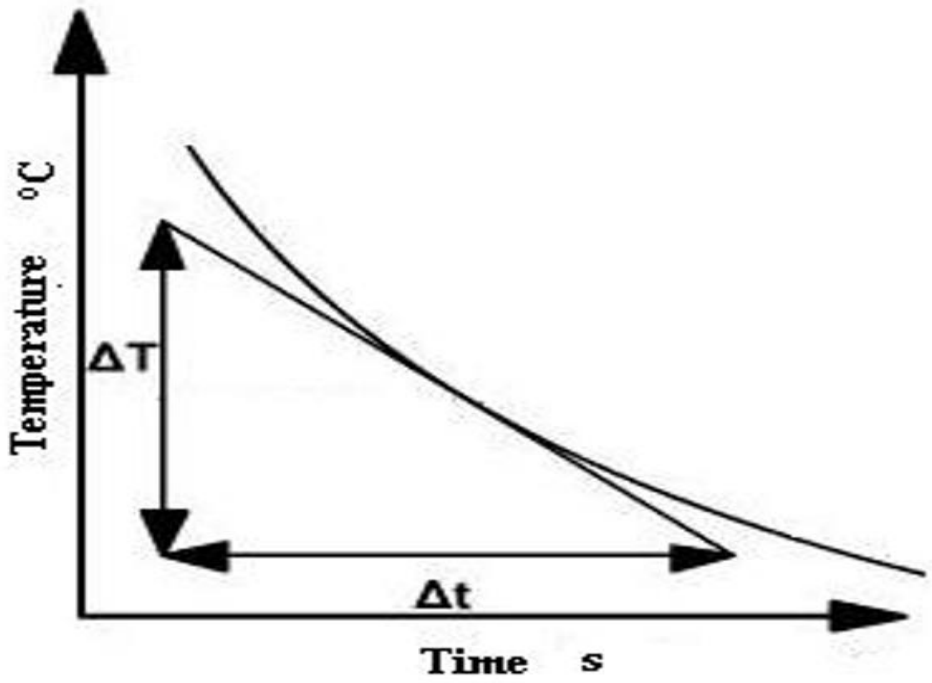

Figure 1: Cooling curve of thermal conductivity analysis of prepared polymer concrete

3. RESULTS AND DISCUSSION

3.1Thermal conductivity of Prepared Polymer Concrete

Table 1: Thermal conductivity observation of prepared polymer concrete containing unsaturated polyester resin and white sand at various compositions

Prepared polymer concrete composition	Thermal conductivity, $Wm^{-1}{}^{0}C^{-1}$
0% sand and 100%unsaturated polyester resin	94.39
20% white sand and 80%unsaturated polyester resin	59.89
40% white sand and 60%unsaturated polyester resin	53.30
50% white sand and 50%unsaturated polyester resin	52.48
60% white sand and 40%unsaturated polyester resin	46.70

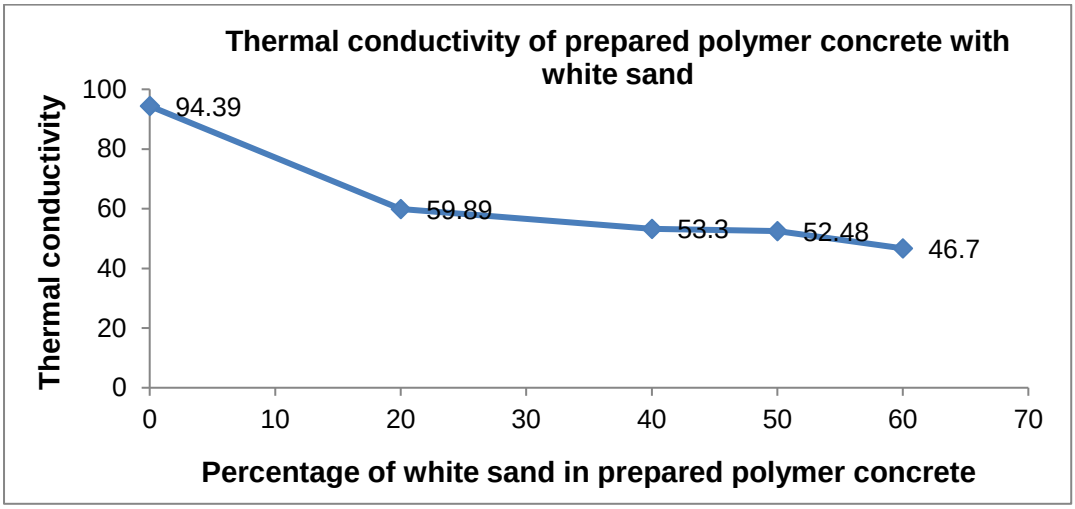

Figure 2: Thermal conductivity of prepared polymer concrete with white sand

From figure 2, it shows that thermal conductivity of prepared polymer concrete has been decreased with increasing of white sand amount in prepared polymer concrete. So it can say that prepared polymer concrete containing high percentage of white sand behaves low thermal conductive properties, on the contrary, prepared polymer concrete containing low percentage of white sand behaves high thermal conductive properties. Porosity of prepared polymer concrete has been increased with increasing white sand amount in prepared polymer concrete. The free path has been decreased resulting in lower thermal conductivity.

3.2 Thermo-Mechanical Analysis of Prepared Polymer Concrete

Prepared polymer concrete of unsaturated polyester resin and white sand has been analyzed by heating the temperature range of 30-90^{0}C in the thermo-mechanical analyzer for observing the linear average co-efficient of thermal expansion. The Linear average co-efficient of thermal expansion (CTE) of prepared polymer concrete has been obtained from thermo- mechanical analysis.

Table 2: CTE at 30-90^{0}C of prepared polymer concrete with white sand

Prepared polymer concrete composition	**CTE at 30-90^{0}C**
Polymer concrete with 0% sand and 100% unsaturated polyester resin	1.16E-4
Polymer concrete with 20% white sand and 80% unsaturated polyester resin	1.29E-4
Polymer concrete with 40% white sand and 60% unsaturated polyester resin	1.35E-4
Polymer concrete with 50% white sand and 50% unsaturated polyester resin	1.39E-4
Polymer concrete with 60% white sand and 40% unsaturated polyester resin	4.69E-5

It has been observed that linear average co-efficient of thermal expansion of prepared polymer concrete of white sand is decreasing with increasing the sand amount in prepared polymer concrete. And decreasing level of linear average co-efficient of thermal expansion of prepared polymer concrete is very small margin.

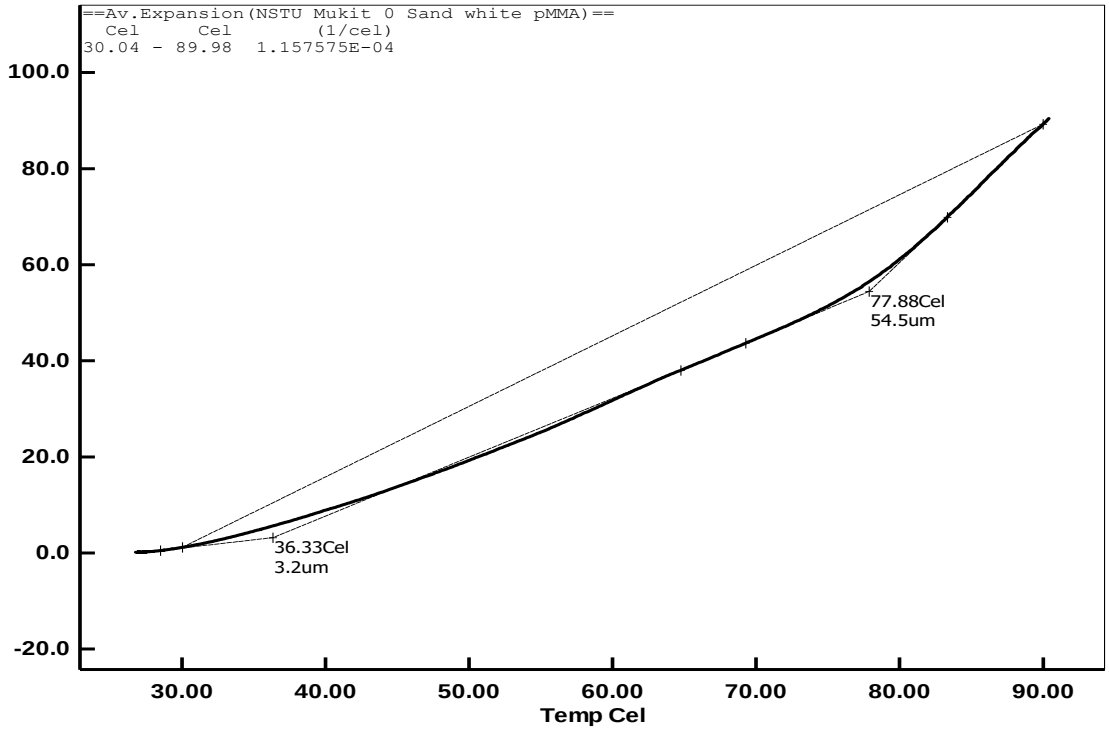

Figure 3: TMA plot of 0% white sand containing prepared polymer concrete

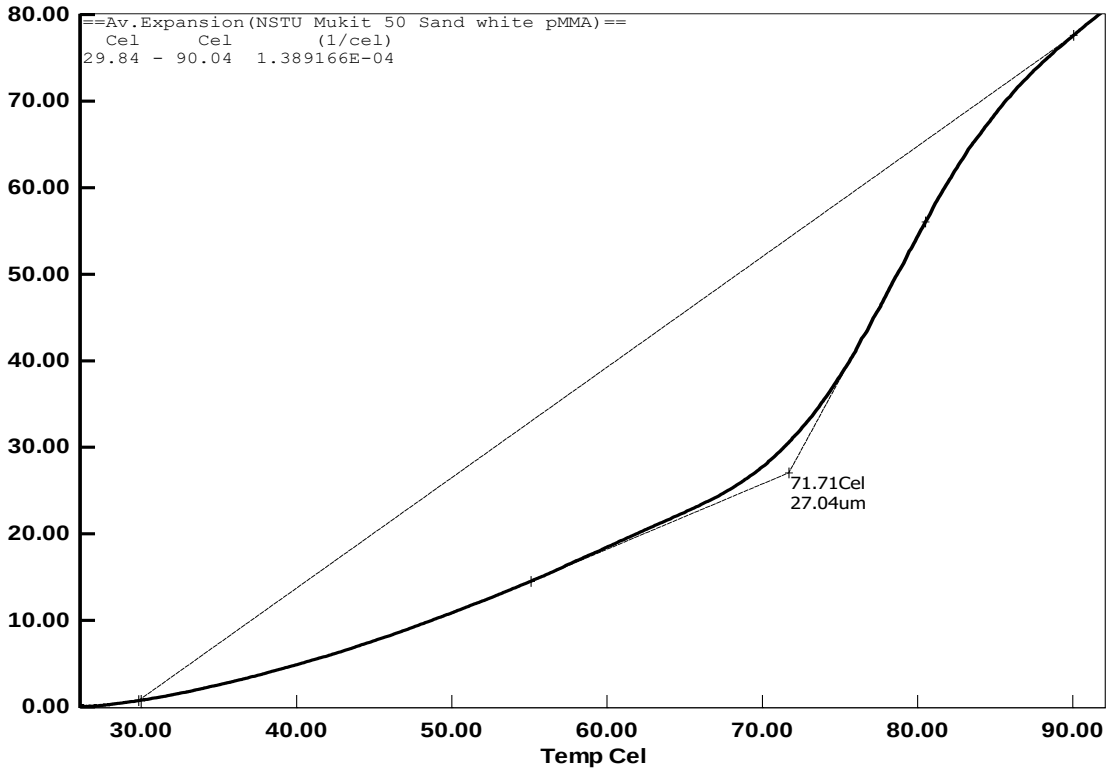

Figure 4: TMA plot of 50% white sand containing prepared polymer concrete

3.3 Thermo-Gravimetric Analysis of Prepared Polymer Concrete

Table 3: Thermal degradation of prepared polymer concrete with white sand

Composition, Onset degradation(°C),	50%degradation,	Max. Slope, Max. degradation rate
0% white sand containing sample,	342.8	382249.51.574 mg/min
50% white sand containing sample,	336.6	387.0249.41.502 mg/min
60% white sand containing sample,	338.0	369.0251.81.601 mg/min

Thermo-gravimetric is one of the methods of thermal analysis. The maximum degradation rate is 1.574 mg/min that has been found for polymer concrete without sand. The maximum degradation rate of polymer concrete containing 50% and 60% white sand have been increased slowly.

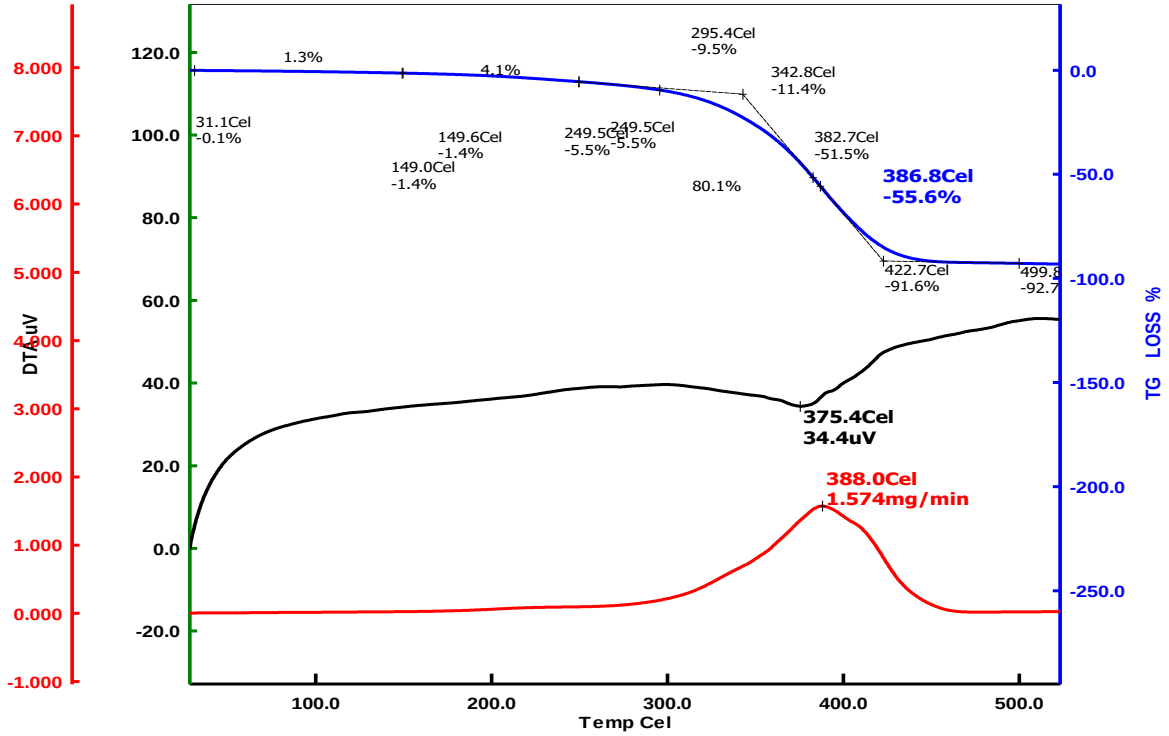

Figure 5: TGA plot of 0% white sand containing prepared polymer concrete

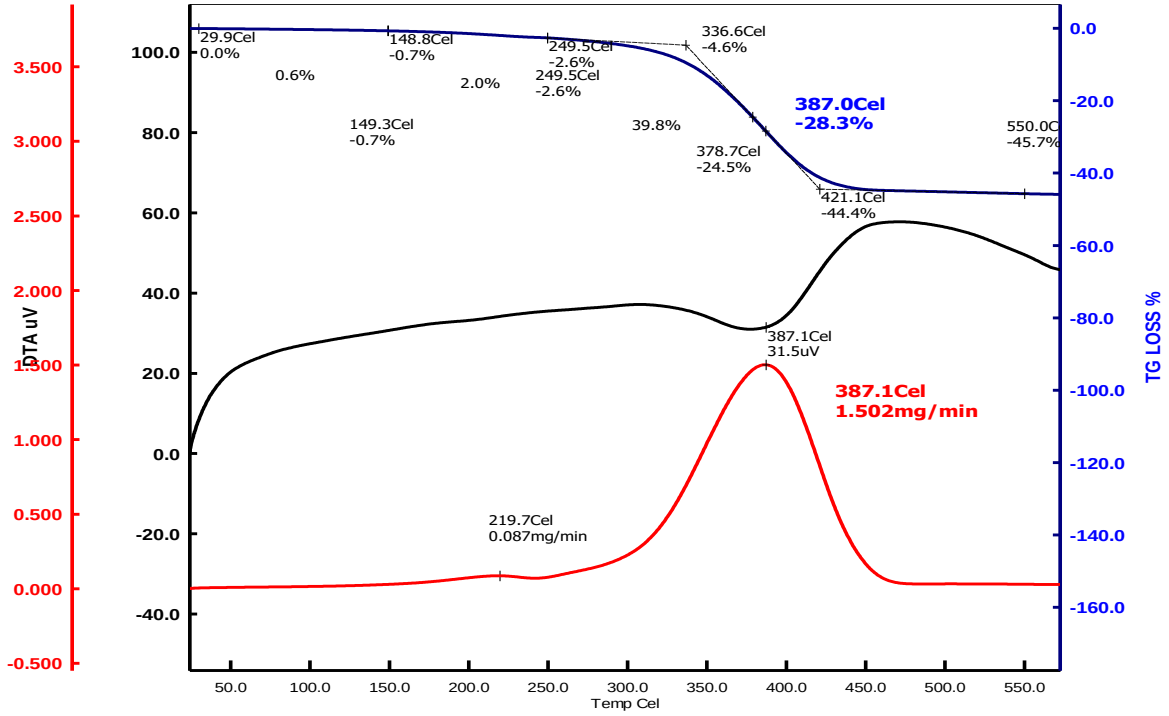

Figure 6: TGA plot of 50% white sand containing prepared polymer concrete

4. CONCLUSIONS

Polymer concrete has been introduced in the late 1950s and became well known in the 1970s for its use in repair, thin overlays and floors, and precast components. In this research work, the features of prepared polymer concrete from unsaturated polyester resin reinforced with white sand have been analyzed. The thermal conductivity, thermo-mechanical properties and thermo-gravimetric properties have been calculated and quantified. The thermal properties of the polymer concrete play important role in the behavior of concrete at elevated temperature. These properties have been studied and the prepared polymer concrete can be considered for using as an acceptable construction material. It is well known that polymer concrete exhibits far better thermal properties than ordinary Portland cement concrete. Polymer concrete has proven itself to be a material which holds much promise due to its better thermal properties. So, at the end of research, it can say that polymer concrete from unsaturated polyester resin and white sand will be found application in very specialized domains in the field of construction.

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