# STUDY OF THERMAL ANALYSIS OF SELECTED CELLULOSE FIBRES

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**Abstract**

This paper provides the investigation of thermal analysis of cellulose fibres which will be used into building materials as a partial filler replacement. Cellulosic fibres come from two various sources: bleached wood pulp and unbleached waste paper whereas these natural fibres have different cellulose contents and another manufacturing process. Natural fibres have been widely used as reinforcing fillers in composite materials in recent years. As a result, they are subjected to thermal degradation during composite processing. It is thus of practical significance to understand and predict the thermal decomposition process of natural fibres and the knowledge will help better design the composite process and estimate the influence on composite properties by the thermal decomposition of natural fibres. The results obtained from the thermal analysis of cellulosic fibres showed differences in their thermal decomposition and also differences in the weight loss due to their chemo-mechanical treatment, the presence of impurities and $CaCO_3$ originating from filler in paper making.

**Key words:** cellulose fibres, thermal analysis, TGA curves

## 1 INTRODUCTION

In the coming years, the construction industry has the challenge of incorporating sustainability in their production processes, either by searching for new raw materials and products more environmentally friendly and/or contributing to the reduction of $CO_2$ emitted into the atmosphere. The possibility of incorporating waste from other industrial activities in their production processes can help with the solution of this goal [1]. Special attention should be given to natural fibres in respect to energy conservation and environment protection. In fact, these materials possess many advantages like low density, high specific strength, no health hazards, and also availability as renewable resources [2]. Fibres such as coir, sisal, banana, hemp hurds, pineapple, wood or recycled paper fibres, present the vast diversity of applications because of their unique properties and the possibility of mass production at affordable cost, while contributing to the biodegradation and renewal of the ecological cycle [3]. The relationship between the individual cellulose fibres in natural material is essential for industrial applications as well as for the processing and the quality of the final fibrous products [4]. Thermogravimetric analysis has practical significance to understand and predict the thermal properties of natural fibre constituents for the rational design of biomass conversion and material processing technologies. Their evaluation provides accurate predictions of biomass behaviour under different thermal conditions that will be useful for their processing/conversion and later specific applications [5]. For practical engineering applications, however, it may be sufficient to consider only the basic characteristics of the thermal decomposition process with some simplified mechanisms. For natural fibre reinforced composite processing, it is of more practical relevance to understand and predict the thermal decomposition of the reinforcing fibres based on parameters at specific process temperature of natural fibre composites [6].

Several studies have investigated the effects of the partial replacement of inorganic binder by cellulosic fibres such as wood fibre waste, rice husk ash, and limestone powder waste, or short curaua fibres and sisal fibres for producing a lightweight concrete block and cement composite as a building material and impact on their physical and mechanical properties [1,2].

Nowadays, cellulosic fibres are utilized in many sectors. They are coming from different sources such as wood, agricultural waste and waste paper which are widely available around the world as renewable natural sources. It can be used as filler/binder replacement or has its function in the reinforcement of cement matrix in building materials and improvement properties of materials which could be used in construction industry. There is more important to make use of various natural cellulosic fibres and so protect the environment, encourage the sustainability of buildings and the development of eco-friendly building materials.

The objective of this work is to investigate the thermal decomposition process of natural fibres from wood pulp and recycled paper.

## 2 MATERIALS AND METHODS

### 2.1 Materials

Six cellulose fibres Greencel including fibres from bleached wood pulp and unbleached recycled paper were used in this study. The Greencel fibres were provided by the company Greencel Ltd (Hencovce, Slovakia). The cellulose fibres are shown in Figure 1. The information on physico-chemical properties of the Greencel cellulose fibres is given in Table 1.


**Fig. 1 White (wood pulp) and grey (recycled paper) Greencel cellulose fibres**

**Tab. 1 Physico-chemical characteristics of Greencel fibres**

| Cellulose fibres sample | Cellulose content [%] | Bulk density [kg/m3] | Max length [µm] | Dry matter [%] | Ash [%] | pH | Colour |
|---|---|---|---|---|---|---|---|
| G 250WT | 80 | 80-100 | 500 | 93 | 20 | 7±1 | white |
| GW-500 | 99.5 | 60-80 | 500 | 93 | 0.5 | 6±1 | white |
| W 640 | 99.5 | 35-45 | 1000 | 93 | 0.5 | 6±1 | white |
| G–500T | 80 | 50-100 | 400 | 93 | 20 | 7±1 | grey |
| G–700T | 80 | 40-70 | 600 | 93 | 20 | 7±1 | grey |
| G–3/00T | 80 | 30-50 | 1200 | 93 | 20 | 7.5±1 | grey |

### 2.2 Thermal analysis

Thermogravimetric analyses (TGA) were carried out with a Jupiter STA 449F3 instrument (Netzsch, Germany). The thermal decomposition of the samples was monitored from 25 °C to 1000 °C under inert atmosphere (nitrogen), at a heating rate of 10 K/min, and an alumina TG crucible was used. The sample mass of 8 ± 1 mg was used for the experiments.

## 3 RESULTS AND DISCUSSION

Thermogravimetric analysis (TGA) is a very useful thermal analysis technique to investigate the thermal stability of a material, or to investigate its behaviour in different atmospheres (e.g., inert or oxidizing) [7]. Figure 2 and Figure 3 show the results of the thermogravimetric analysis performed on the wood pulp fibres and recycled paper fibres, respectively. The results indicated slight differences between the evolution profiles of the thermal degradation TGA of the six samples. Common behaviour observed for all samples is the dehydration process, in which 0.55 – 1.22 % of water is removed in the temperature range between 25 °C and 127 °C. This loss mass depends on the initial moisture content of the fibres. The second decrease in weight of the cellulosic fibres was observed at 206 – 400 °C and the maximum decrease in weight loss was noticed at these temperatures. For the fibres from wood pulp and recycled paper, the weight loss was 66.71, 78.62, 80.94 %, and 48.45, 50.85, 56.13 %, respectively. It is widely accepted that the primary thermal decomposition of cellulosic materials occurs between 200 and 400 °C. The initial decomposition of the cellulosic components takes place mostly in the amorphous regions [8]. This stage of weight loss is due to the decomposition of major components of the fibres. According to Kim et al. [9], the depolymerization of hemicellulose occurs between 180 and 350 °C, the random cleavage of the glycosidic linkage of cellulose between 275 and 350 °C [10]. Although the decomposition of residual lignin had started as early as 160 °C, it decomposes slowly and extends its

temperature as high as 900 °C to complete its decomposition [11]. The cellulose molecule is a very long polymer of glucose units, and its crystalline regions improve the thermal stability of fibres [10]. The higher onset of degradation temperatures indicates the improved thermal stability of the material [11]. Celluloses have higher thermal stability probably due to a much higher amount of hydrogen bonds between cellulose chains that can lead to more ordered and packed cellulose regions, this in turn possibly increasing the thermal decomposition temperature of cellulose [12]. In the sample GW-500, mass loss 12.71 % is observed in the temperature range between 431 °C and 568 °C. The recycled fibre, G–700T, reveals a mass decrease of 15.66 % in the temperature range between 388 °C and 604 °C. In the temperature range 604 °C to 747 °C, the decomposition of $CaCO_3$ (coming from manufacturing processes) ran and it was possible to find some impurities. In this part of cellulose fibres, the thermal decomposition weight loss is 10.19 % for G 250WT and 8.3, 10.92, 10.04 % for the recycled fibres, respectively. The last phase started from the end of previous phase and continued to 1000 °C. There is also a distinction between the amounts of the residues of the fibres 13.35, 4.22, 2.77 % and 24.65, 22.10, 19.02 % remaining at 1000 °C heating for bleached wood pulp and recycled fibres, respectively.

The obtained results showed that the thermal stability of lignocellulosic materials increased after the chemo-mechanical treatments. This could be attributed to the removal of hemicellulose and lignin during the chemical treatments as well as to the higher degree of crystallinity in the material after processing. The alkaline and bleaching treatments were used to the removal of non-cellulosic constituents as well as to the degradation of amorphous regions in the cellulose and increased the degree of its crystallinity. Consequently, the greater crystalline structure led to a high resistance towards heat and an increase in the maximum temperature for thermal degradation [8].

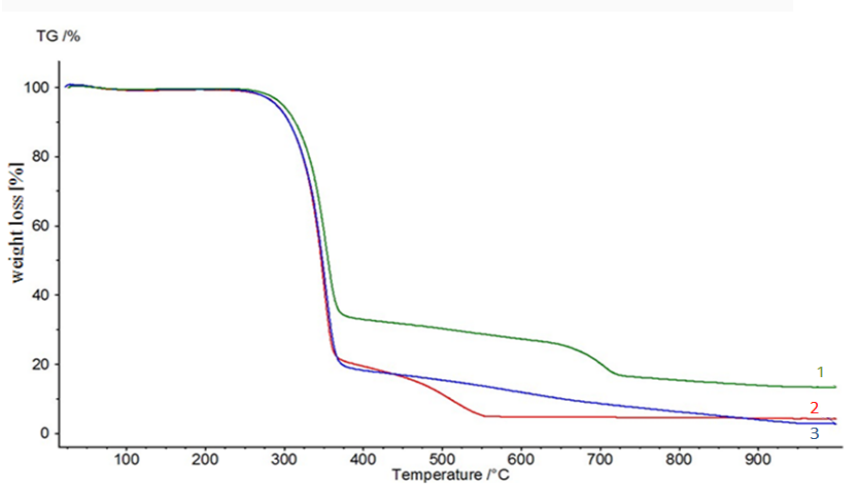


**Fig. 2 TGA curves of wood pulp fibres; 1 – G250W; 2 – GW-500; 3 – W640**

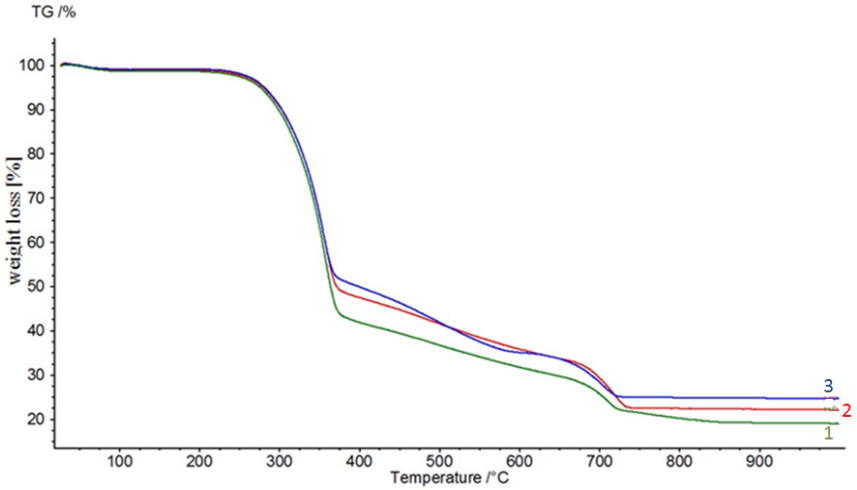


**Fig. 3 TGA curves of recycled waste paper fibres; 1 – G-3/00T; 2 – G-500T; 3 – G-700T**

## 4 CONCLUSION

This study presents the thermal behaviour of two types of cellulose fibres characterized by TGA analysis. Studying the thermal stability of six samples of the cellulose fibres from wood pulp and waste paper showed differences in their thermal decomposition, and also differences in the weight loss were observed. These differences are caused by their various cellulose contents in fibres, the presence of impurities and $CaCO_3$ originating from filler in paper making. Investigation of the thermal properties of the natural fibres is important in order to gauge their applicability for the processing of biocomposite. Other properties of cellulose samples will be tested by next physico-chemical methods using TGA/DSC and XRD analyses. The subject of further research work will consist in the introduction of these two types of cellulosic fibres different in nature into cement mortars in various percentage portions and the subsequent testing of their influence on physico-mechanical parameters of the fibre-cement mortars.

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