東京理科大学「火災安全科学研究拠点」

Tokyo University of Science “Research Center for Fire Safety Science”

■研究成果概要報告書/ Report for Outline of Research Results

| 研　究　課　題<br>Research Topic | | Analysis of fire / combustion characteristics of laminated wood (glulam) | 実 施 年 度<br>2016 |
|---|---|---|---|
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１．研究の背景および目的/ Background and Aim of Research

Glued laminated timber, also called glulam, is a type of structural timber product comprising a number of layers of dimensioned timber bonded together with durable, moisture-resistant structural adhesives.

By laminating a number of smaller pieces of timber, a single large, strong, structural member is manufactured from smaller pieces. These structural members are used as vertical columns or horizontal beams, as well as curved, arched shapes. Glulam is readily produced in curved shapes and it is available in a range of species and appearance characteristics to meet varied end-use requirements. Connections are usually made with bolts or plain steel dowels and steel plates.

Glulam optimizes the structural values of a renewable resource – wood. Because of their composition, large glulam members can be manufactured from a variety of smaller trees harvested from second- and third-growth forests and plantations.


In order to take advantage of the laminated wood as a building interior material, analyzing the characteristics of the fire it is very important. Wood has very strong resistance to fire because wood form a carbide layer in the combustion process.

Despite these fire characteristics, if the laminated wood is exposed to fire, new forms of problems are occurred. When the glulam is continuously exposed to heat, the explosion of inside is occurred. These explosion phenomenon becomes greatly threaten safety of inside and rapidly destroy the structure.

Binder used for producing glulam is reason. Fully curing binder is degraded to single molecule by high temperature. Binder monomolecular is will be rapidly burned. As the internal combustion progresses, leading to the explosion.

Therefore, there is a need for research to analyze the combustion characteristics with degradation products of glulam. In particularly, any change of glulam it causes in the fire environment must analyzed through a quantitative evaluation.

２．利用施設及び利用日/ Facility and Schedule

- 装置　（2016 年 11 月 6 日 ～ 11 月 10 日）
  - Visit evaluation (Glulam, Cone calorimeter)
- 装置　（2017 年 4 月 ～ 5 月 ）
  - Commissioning evaluation (CLT, Cone calorimeter / FT-IR Toxic test)

３．実験方法・研究成果、および考察（申請時の計画に対する達成度合いも含む）
※継続課題の場合は，前年度との関係性，進展度合いについても記載すること。
/ Method, results, and conclusions (degree of achievement compare to application)

## The first experiment

**1. To check the flame retardant properties of the glued laminated wood (2016 11 月).**

- To analyze the burning characteristics according to the surface treatment (flame retarding treatment) of the glued laminated wood.
- Surface treatment by surface coating / dipping method and evaluation of flame retardant characteristics
- Cone calorimeter experiment only

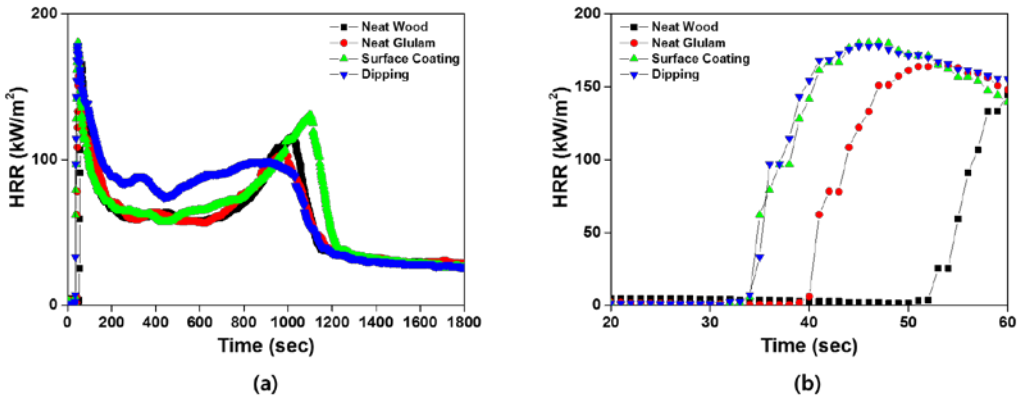



**Figure 1. Cone calorimeter test with surface treated glulam**

**2. Analysis of experimental results**

- Combustion characteristics were analyzed at 50kW.
- Neat wood and Neat glulam have almost similar combustion characteristics.
- As the surface carbonization layer is formed, the burning rate is delayed, and secondary combustion starts.
- Glulam basically uses solid wood as base structure.
- In the case of surface treatment, tendency to accelerate combustion early
- It is judged that low molecular substance plays a role of accelerating combustion.
- General flame retardant coating has little effect on complete combustion condition (50kW).

## The second experiment

**Flame retardant test of CLT (2017 3 □ with KCL in Korea)**

- The direction of experiment was changed through the first evaluation.
- Glulam to CLT changed the subject.
- The CLT is used for the plates that make up the wall or floor of a building.
- Recently, studies are being actively carried out to use CLT for linear structure.
- A multilayer structure is proposed for the flame retardant properties of CLT.
- Intumescent system is adopted to maximize the flammability.
- Intumescent system is a technology that forms a foam structure. The effect of fire retardation is great through the formation of surface carbonized layer.

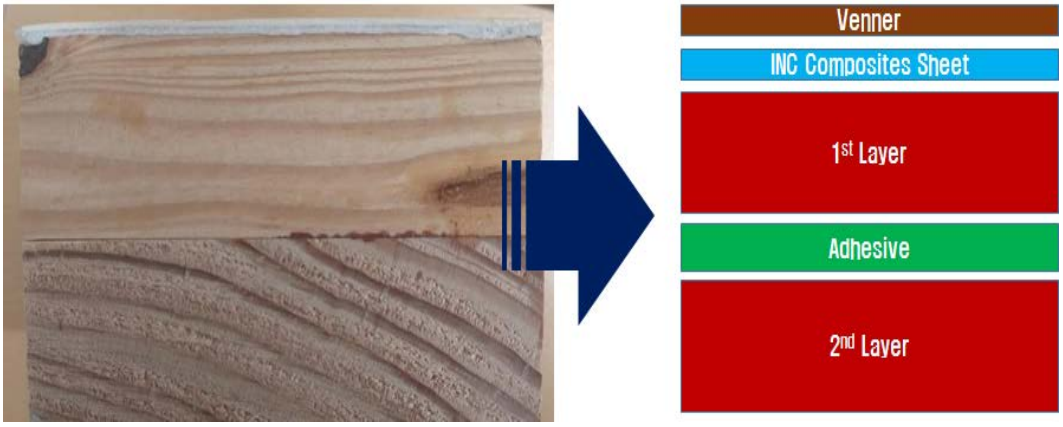



**Figure 2. The newly proposed multi-layered flame retardant CLT**

- - A thin veneer was attached to the outermost part to maintain the appearance of CLT.
- Veneers are susceptible to fire and therefore vulnerable to initial combustion. However, the combustion of the composite material is delayed due to foaming.
- EVA was selected to attach the veneer. In the secondary combustion process, a rapid increase in the heat of combustion is confirmed.
- On the other hand, maximum peak is decreased when using intumescent system.
- It can be confirmed that the effect is greater than that when Clay is applied.
- In the case of Clay, the insulation effect is realized by forming a layer on the surface.

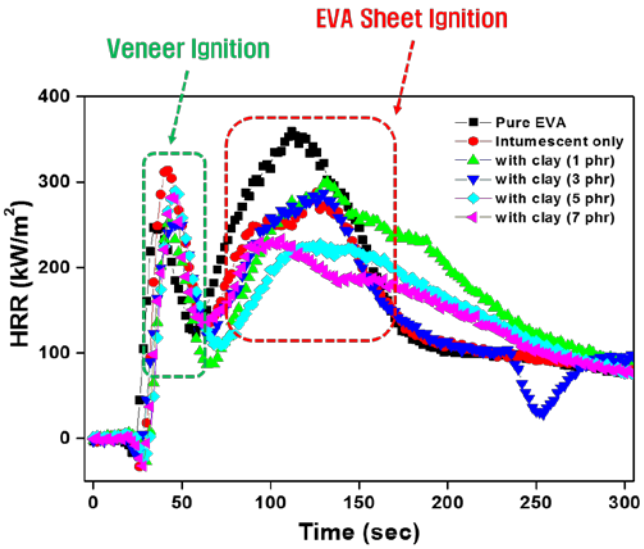



Figure 3. Cone calorimeter test with multi layered CLT

## The third experiment

### Toxic gas test of CLT (2017 4~5 □ )

- FT-IR was performed for toxicity evaluation. (25kW condition)
- Main by-products were tracked and evaluated.
- The main evaluation subjects are water vapor, carbon dioxide, carbon monoxide, nitrous oxide, formaldehyde, ethane and propane.

Figure 4. Sample after toxicity evaluation

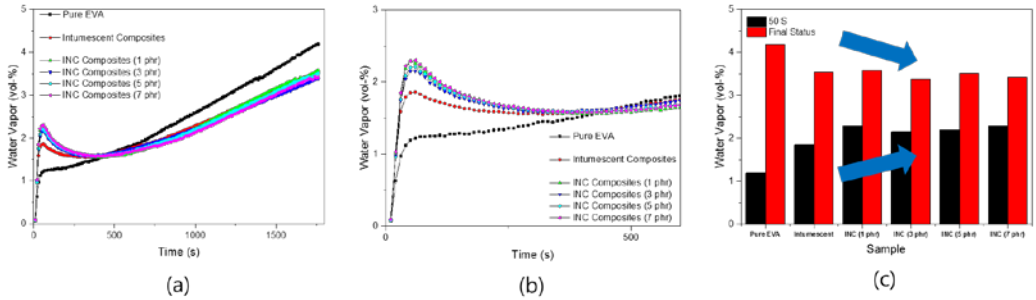



Figure 5. Water vapor test results (a) Overall results (b) Initial results (c) 50 sec./final condition

- In the discharge test of water vapor, it can be confirmed that the initial water production is accelerated in the sample where the combustion characteristics are

strengthened.

- The ratio is up to 2 times.

- The reason for the increased water production is from the pentaerythritol contained in the intumescent system.

- pentaerythritol is condensed and water is generated. Therefore, the amount of water generated is higher than that of the intumescent system.

- If Clay is applied together, the amount will increase further.

- In the case of Clay, the surface is treated with OH, and a condensation reaction occurs in the combustion process. These characteristics are considered to be reflected in the combustion characteristics.

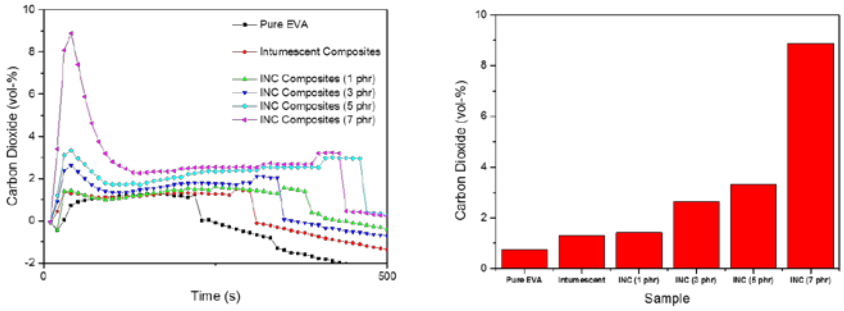



**Figure 6. Carbon dioxide test results**

- Carbon dioxide is an index of combustion.

- When the Intumescent system is applied, the occurrence of carbon dioxide increases.

- There are two major causes.

- The first is due to the scissoring effect of molecular structure shortening in the process of making EVA composites.

- Since the polymer is deteriorated in the high temperature extrusion process, it becomes easier to burn.

- The second is due to the oxygen of the intumescent system and clay.

- Because combustion is determined by the efficiency of oxygen, it is evaluated as an effect on it.

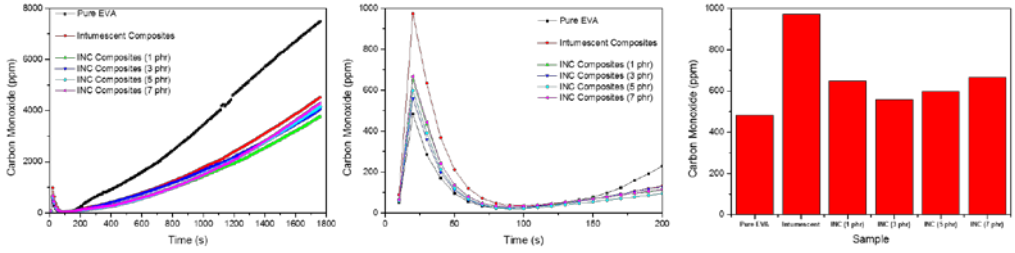



**Figure 7. Carbon monoxide test results**

- Carbon monoxide is an indicator of incomplete combustion.
- As the Intumescent system is applied, the incidence of monoxide increases rapidly in the beginning.
- However, over time, the overall rate of occurrence decreases.
- It seems that this tendency appears with the decrease of overall combustion.

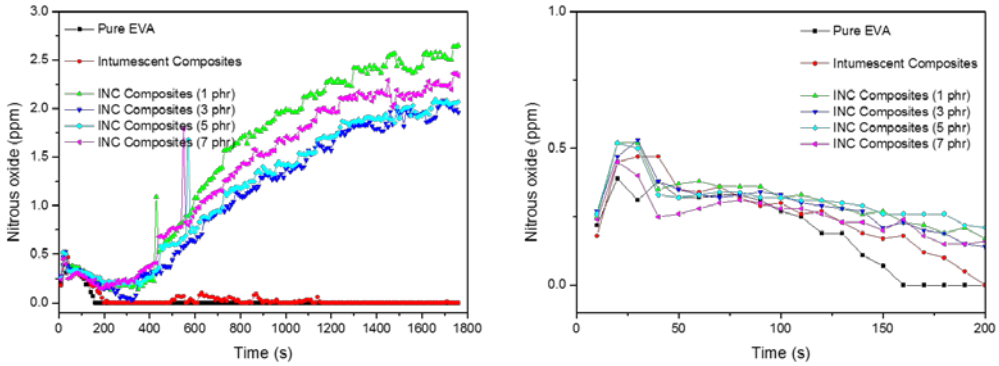



**Figure 8. Nitrous oxide test result**

- Nitrous emissions assessment results are very characteristic.
- Intumescent system is likely to cause nitrogen compounds because it utilizes melamine.
- In the case of Pure, only a small amount occurs in the early stage, and no occurrence occurs in the latter period.
- On the other hand, when the clay is applied, the amount of the generated clay tends to increase sharply.
- This is cause that clay surface oxidation process

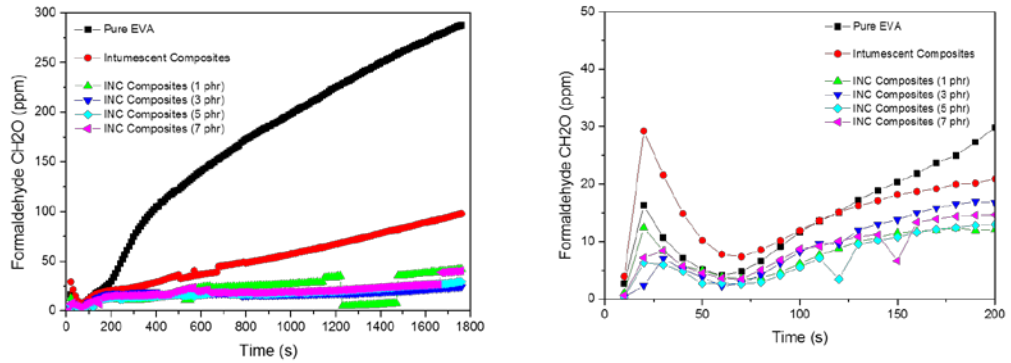
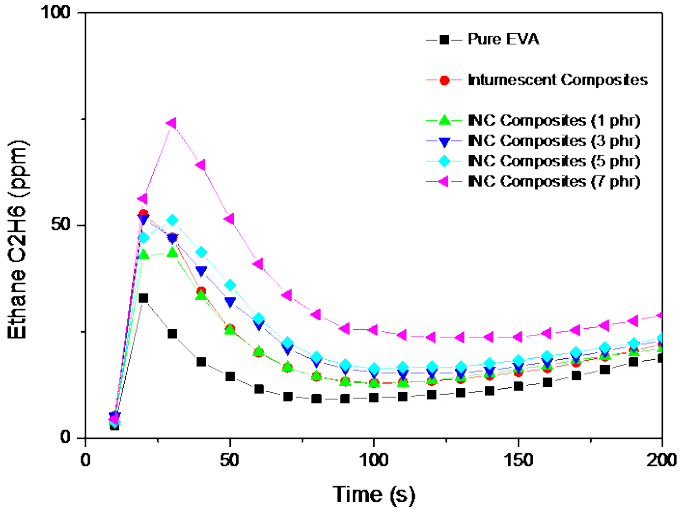


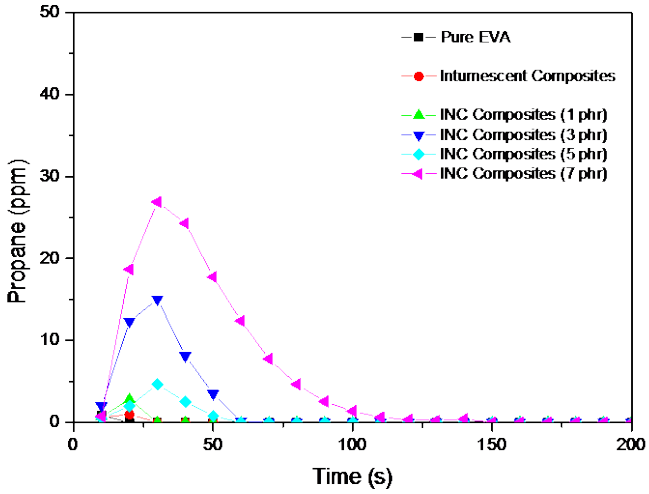

**Figure 9. Formaldehyde test result**

- In the evaluation of formaldehyde, which is a representative toxic substance, reduction effect is very large when intumescent system is applied.
- When Clay is applied, the total amount of dissipation decreases greatly.
- With the Intumescent system, initial emissions are increasing, but sustained emissions

tend to decrease.

- If Clay is applied, the amount of generation will decrease from the beginning. This is because the combustion efficiency is increased more.




- Despite the overall reduction in toxicants, the initial production of hydrocarbons is estimated to be more accelerated.

- Hydrocarbons can act as the main material for secondary combustion. It is estimated that the generation of such hydrocarbons induces acceleration of the overall combustion.

４．今後の展望（今後の発展性，見込み等についても記述）／ Future Perspectives

- Explore various structures to maximize flame retardant effect
- Study of Hybrid System of Surface Treatment and Multi-layer Structure System
- Analysis of Combustion Characteristics and Toxicity Characteristics according to Material Changes

５．成果の公表状況（学会への発表，学術誌への投稿等を記述。予定も含む）
/ Publishing (presentation, paper, etc. incl. plans in the future)

- Participating in international conferences (2018 World Conference on Timber Engineering, Korea 2018)

- Two or more SCI papers will be submitted
  - Surface treatment and flame retardant characterization of CLT (June, 2017)
  - Tracking the release of toxic substances from CLT (February, 2018)

６．経費の使用状況 / Usage of Budget

| expendables・Meeting・Printing | | Travel expense | | Personnel expenses | |
|---|---|---|---|---|---|
| Contents | Cost | Contents | Cost | Contents | Cost |
| ＦＴＩＲ用フィルター<br>ＦＴＩＲ用ＳＯ２チェックガス | 189,000<br>50,544 | １１月６日～９日　KIM HYUN-JOONG<br>１１月６日～１０日　PARK JI WON | 17,372<br>18,650 | １１月６日～１０日　PARK JI WON | 9,000 |
| Subtotal | | Subtotal | | Subtotal | |
| Burden of Tokyo University of Science / Total Yen | | | | | |
| Burden of 284,566/ Total Yen | | | | | |

※スペースが足りない場合はページを増やしても構いません。