CHAPTER IV
RESULTS AND DISCUSSION

4.1 XRD Patterns of Bentonite Modification

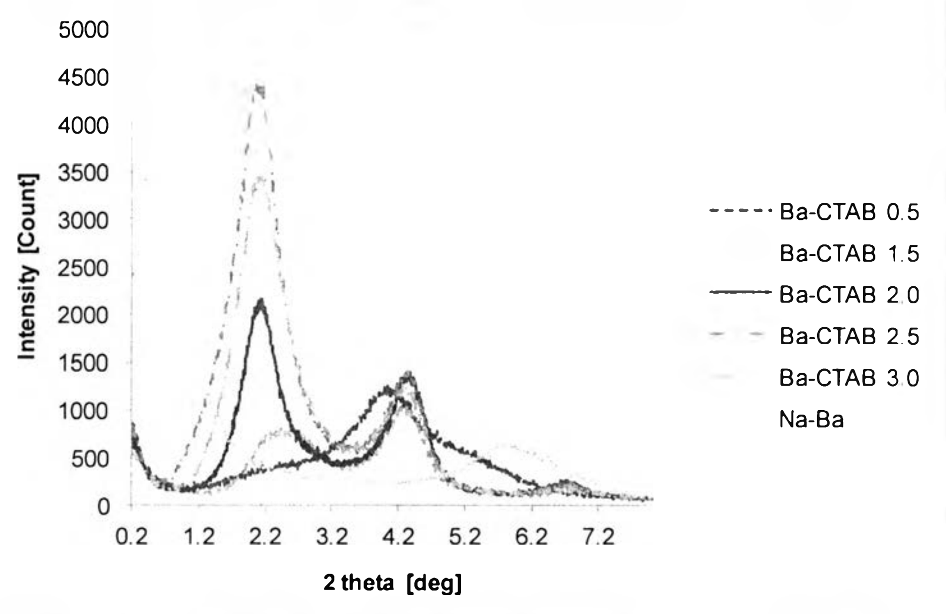


Figure 4.1 XRD patterns of modified bentonite nanoclay at different CTAB levels and untreated bentonite.

Figure 4.1 shows the X-ray diffraction (XRD) spectrum of untreated bentonite clay and organoclay treated with CTAB. Unmodified bentonite clay (Na-Ba) had the diffraction peak at $2\theta = 5.85°$ with the d-spacing of 15.09 Å which disappeared after modification by insertion of CTAB into the clay gallery. The new peak at 20.48 Å, resulted from organic modification, indicateed that the clay gallery was more broaden. The peak at 42.21 Å was the results from the formation of a positively charged bilayer of CTAB on the clay surface, which attracted anions from the solution and formed alkylmetal ions. This adsorptive property was possible when loading of the surfactant was exceeded the cation exchange capacity (CEC) of the clay. This adsorption resulted in a large broadening of the clay gallery. From the figure 1, the loading of CTAB at 2.5 % by weight resulted in highest intensity of metal ions adsorption and, by far, was the optimum loading for CTAB.

4.2 Mechanical Properties of WPC

4.2.1 Effect of MAPP on Mechanical Properties of WPC

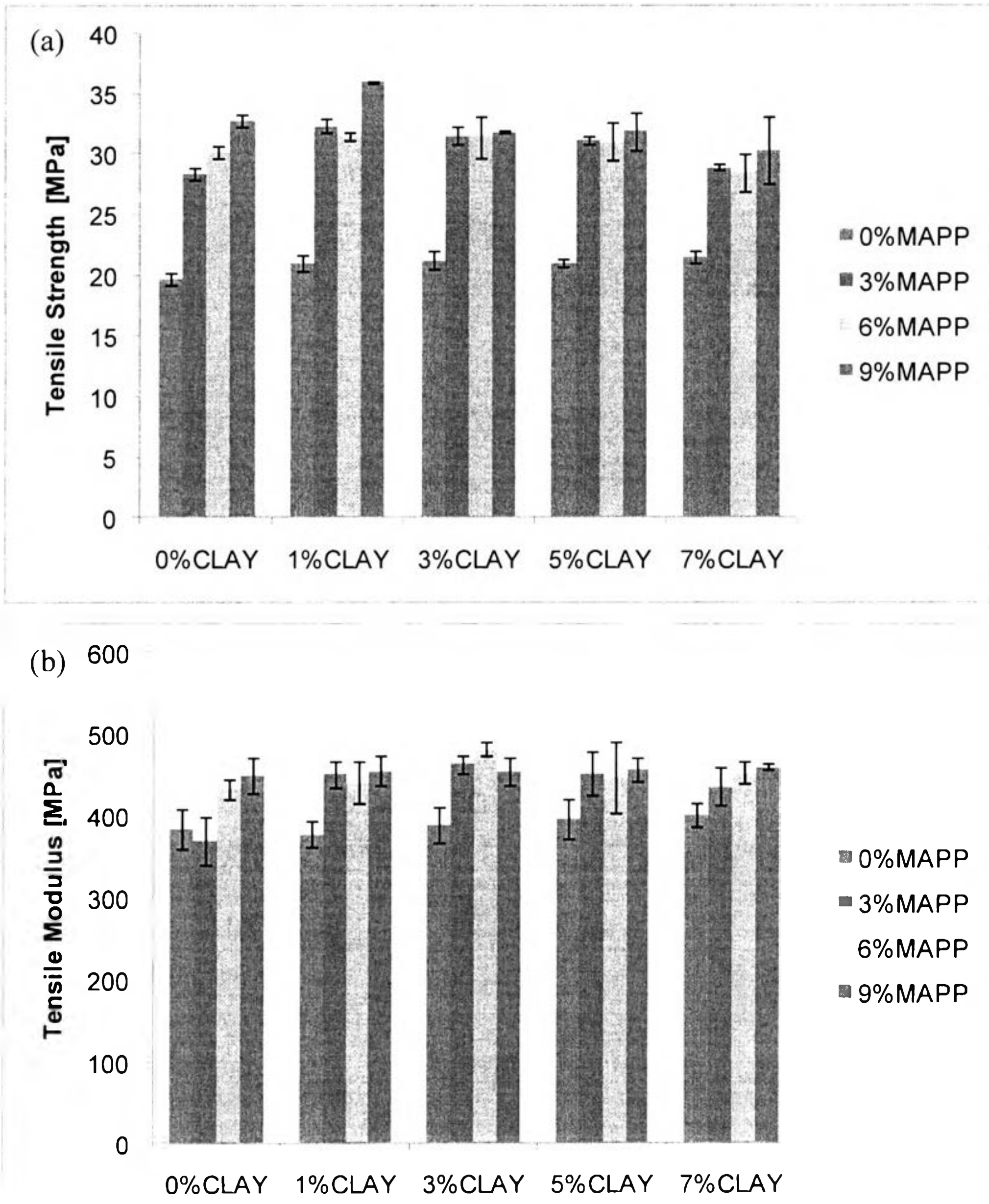


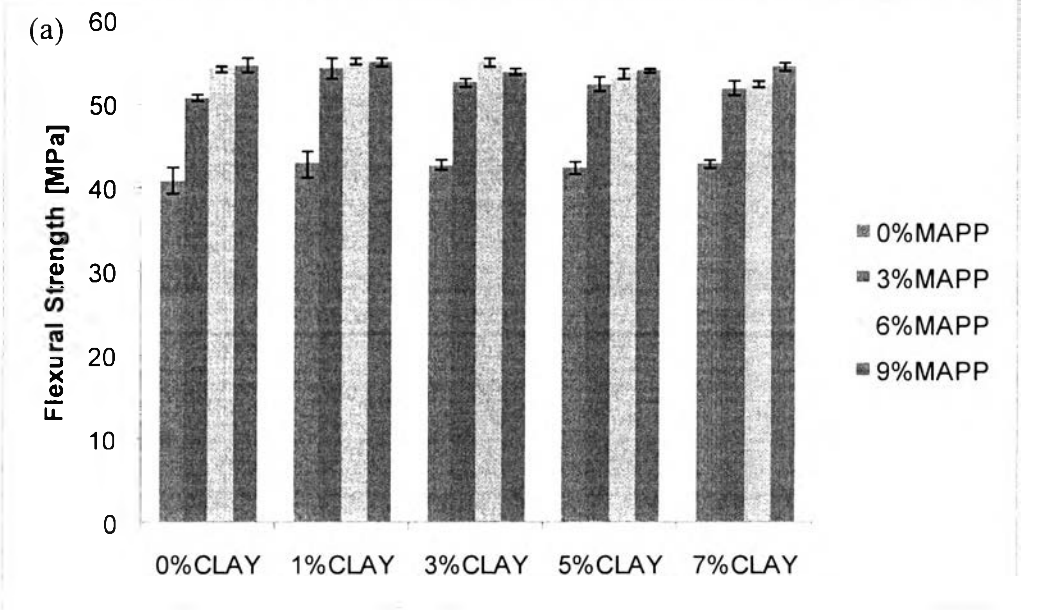
Figure 4.2 Tensile strength (a) and tensile modulus (b) of WPC at nanoclay content of 0%, 1%, 3%, 5% and 7% w/w at different MAPP levels.

From figure 4.2 (a), the addition of MAPP resulted in the improvement in tensile strength. At 0% of nanoclay content, the more MAPP was added, the more strength the specimens were. From these results, the improvement in tensile strength arose from the miscibility between wood flour and PP matrix. Maleic anhydride part of the compatibilizer could form the physical and chemical bonding with the hydroxyl group on the wood surface while the PP part of the compatibilizer could miscibly blended with the PP matrix. This was resulting in the improvement of the surface adhesion between the two phases and, once the tensile force was applied, improved the load bearing of the specimens. The increase in MAPP content, which was varied from 0% to 9%, resulted in the more effective in tensile strength improvement. Because of the higher amount of MAPP gave a better surface adhesion and, therefore, increased of tensile strength. At various ratio of nanoclay content, the presence of MAPP greatly improved the tensile strength of the composites and the higher MAPP content could improve the higher strength. From the results, it was observed that MAPP content at 9%w/w, at every nanoclay ratio, yielded the highest tensile strength and, therefore, it could be concluded the 9% of MAPP was the optimum condition for tensile improvement.

From figure 4.2 (b), at 0% of nanoclay content, the addition of MAPP at 3%w/w showed insignificant change in tensile modulus Tensile modulus related to stiffness of the materials. Without MAPP, there was a phase separation between wood flour and PP matrix. When the load is applied, the matrix deformed without any effect from wood flour. The presence of MAPP improved the interface between two phases and a rigidity of wood flour took part in matrix deformation and made the specimens deform more difficultly. However, the higher content of MAPP resulted in slightly increase of tensile modulus. This indicated MAPP had highly effect in improvement of the tensile strength but slightly affected the tensile modulus.

In the flexure testing, none of these composites showed catastrophic failure. Cracks developed from the specimen bottom and gradually resulted in failure. The effect of MAPP on flexural strength was shown in figure 4.3 (a). The addition of MAPP content at 3%w/w drastically increased the flexural properties of the composites as a result from the improvement of the surface adhesion of PP matrix and wood flour. The further adding of MAPP could increase the strength in a small scale. This tendency remained at the higher content of nanoclay levels. Considering the flexural modulus, figure 4.3 (b) shows an insignificant improvement of flexural modulus at different loading of nanoclay. The higher amount of MAPP adding could slightly alter the flexural modulus. At the higher loading of nanoclay, this tendency remained. This indicated that addition of MAPP had great effect on flexural strength while the modulus was slightly affected.

The impact strength of the composites was shown in figure 4.4. The addition of MAPP resulted in slightly change at low nanoclay loading. The higher addition of MAPP could minimally alter the impact strength of the composites. This was due to rigidity of wood particle and nanoclay. The impact force was quickly applied to the specimens resulted in sudden deformation of PP matrix. The presence of rigid filler, whether good interfacial bonding is achieved or not, would result in impact strength reduction since the rigid filler obstructed the deformation of the matrix instead of improving it. It was concluded that MAPP loading had slightly effect on impact strength.



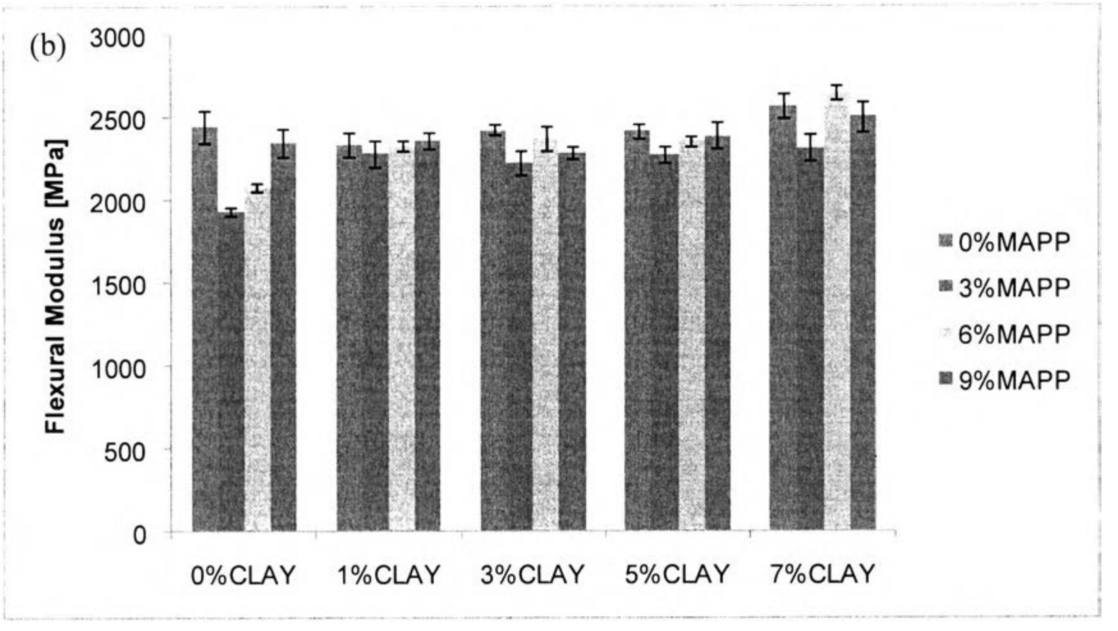


Figure 4.3 Flexural strength (a) and flexural modulus (b) of WPC at nanoclay content of 0%, 1%, 3%, 5% and 7% w/w at different MAPP levels.

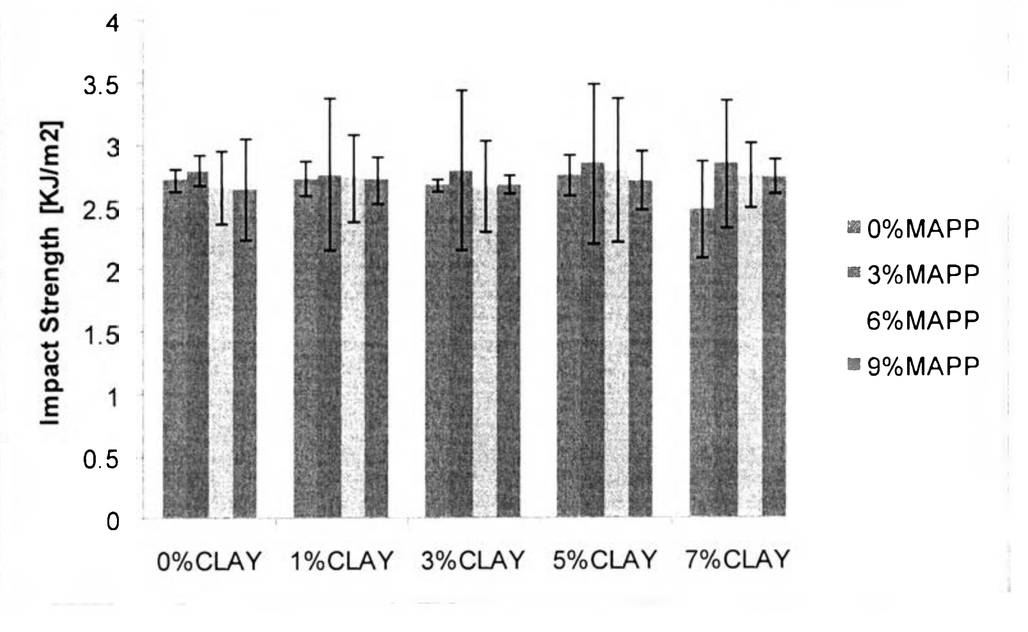


Figure 4.4 Impact strength of WPC at nanoclay content of 0%, 1%, 3%, 5% and 7% w/w at different MAPP levels.

4.2.2 Effect of Nanoclay on Mechanical Properties of WPC

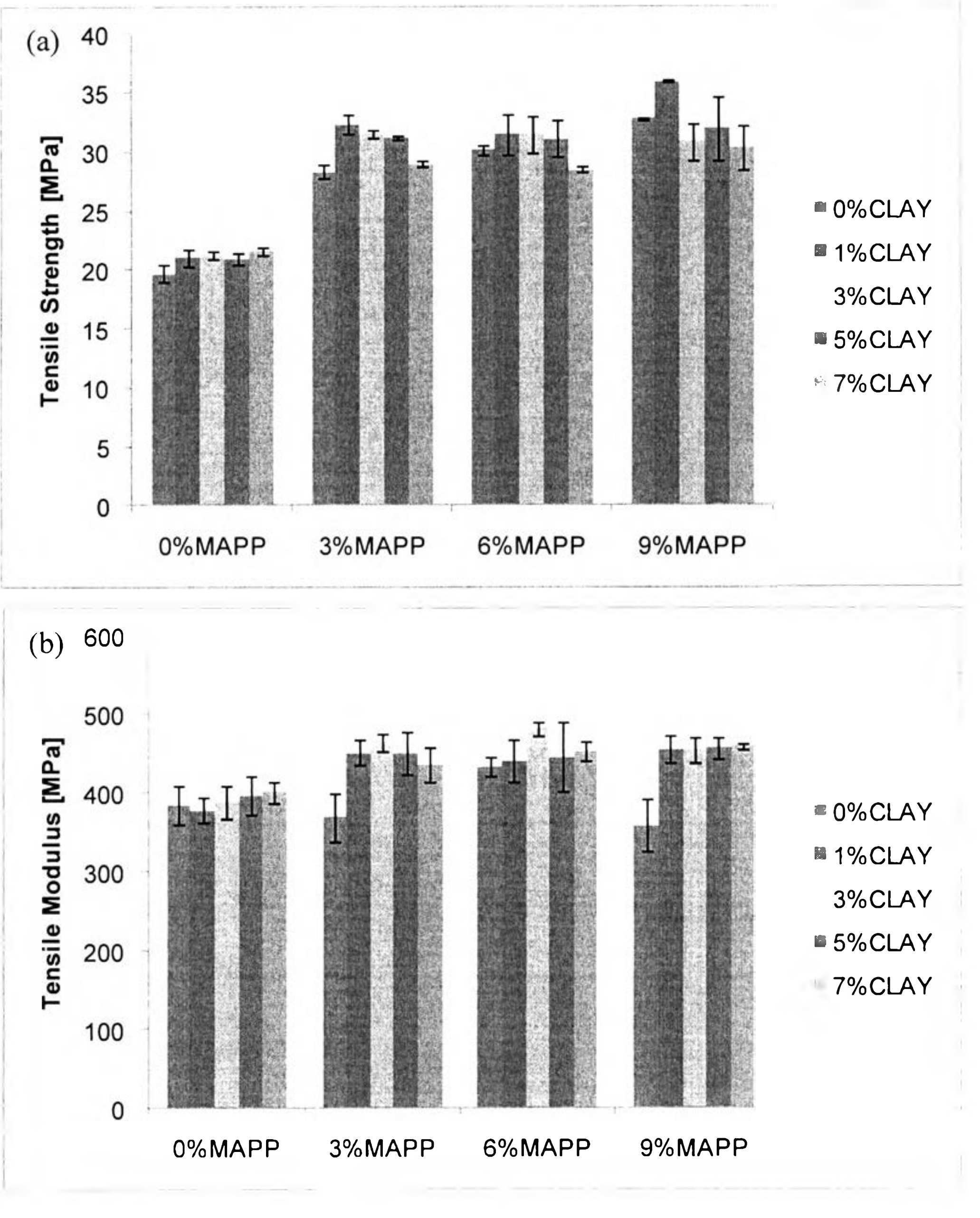


Figure 4.5 Tensile strength (a) and tensile modulus (b) of WPC at MAPP content of 0%, 3%, 6% and 9% at different nanoclay levels.

The effect of nanoclay incorporation on the tensile properties was shown in figure 4.5 (a). The addition of nanoclay (1%, 3%, 5% and 7%w/w) without MAPP addition resulted in insignificant improvement of WPC. The incorporation of nanoclay at 1%w/w slightly improved the tensile strength but at the higher content at 3%, 5% and 7% w/w of nanoclay, tensile strength showed the tendency to decrease. This tendency remained, even though at the higher content of MAPP. This was believed that the high content of nanoclay resulted in partial intercalation or agglomeration which could improve the strength less than exfoliation which took place at low nanoclay loading. Concerning tensile modulus, figure 4.5 (b) shows the results which indicate the slight increment on the modulus when the nanoclay was loaded. It was expected the modulus would decisively increase as the nanoclay was incorporated since the rigidity of nanoclay would directly affect the stiffness of the spacimens. At 0% w/w MAPP, it was turned out that nanoclay loading had insignificant effect on the modulus. This might because of the wood particle was also rigid and the content of wood flour was enormous comparing to little content of nanoclay loading and without compatibilizer, the deformation of matrix was irrelevant to any filler effect. This could explain the reason why the modulus was minimally affected by nanoclay.

In the flexure testing, none of these composites showed catastrophic failure. Cracks developed from the specimen bottom and gradually resulted in failure. The effect of nanoclay on flexural strength was shown in figure 4.6 (a). The addition of nanoclay content drastically increased the flexural strength of the composites. At 1% w/w of nanoclay resulted in the highest flexural strength, but the higher loading of nanoclay showed the tendency to decline. This trend remained when MAPP was added at different content. This might due to the presence of agglomeration or partial intercalation at high nanoclay content. Flexural modulus showed in figure 4.6 (b) indicates the increase of the stiffness as the nanoclay content was increased. At the higher content of MAPP, the addition of nanoclay also increased the flexural modulus. This was understandable phenomenon since the addition of rigid particle of nanoclay would directly affect the stiffness of the specimens and, therefore, increase the flexural modulus of the specimens as well.

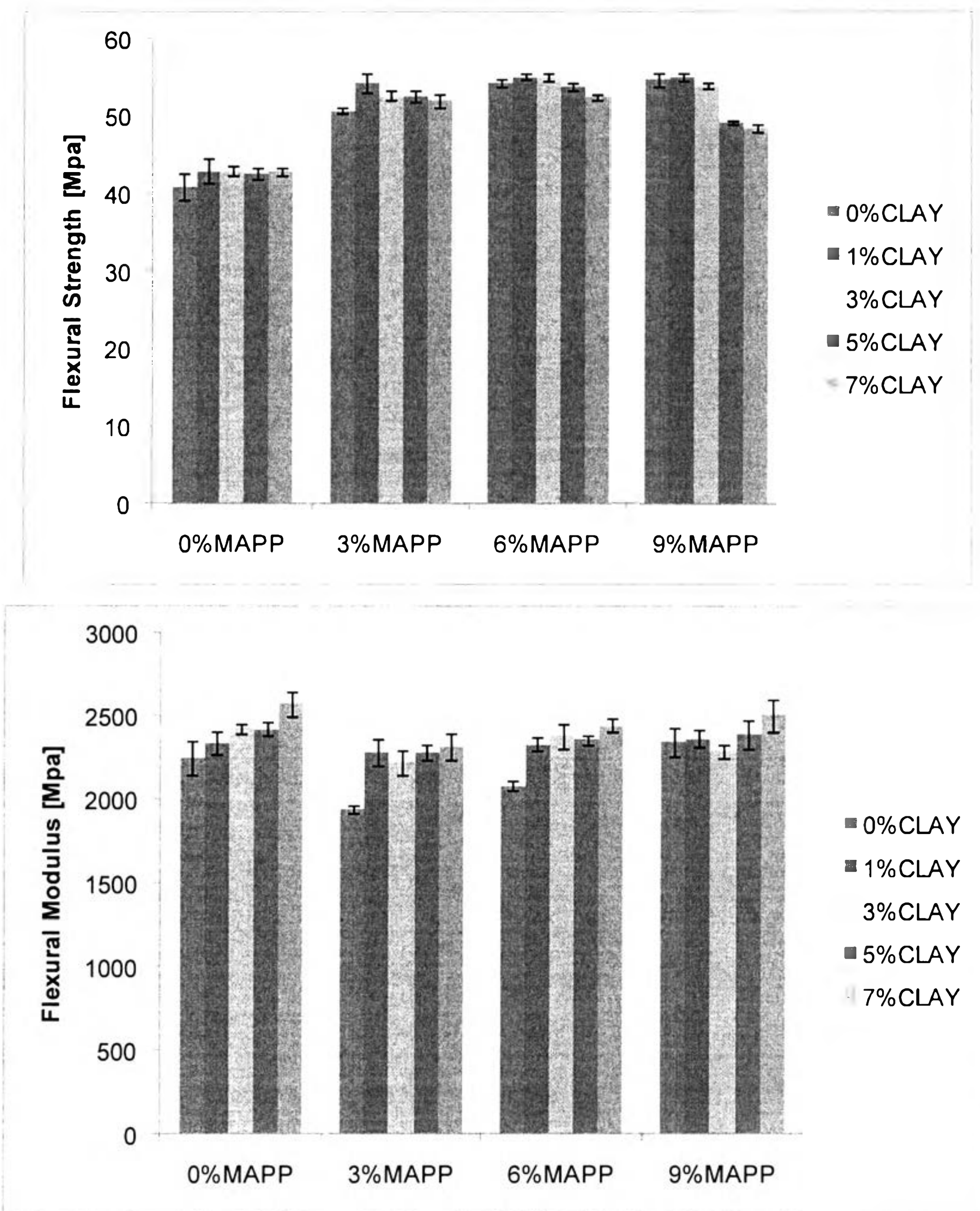


Figure 4.6 Flexural strength (a) and flexural modulus (b) of WPC at MAPP content of 0%, 3%, 6% and 9% at different nanoclay levels.

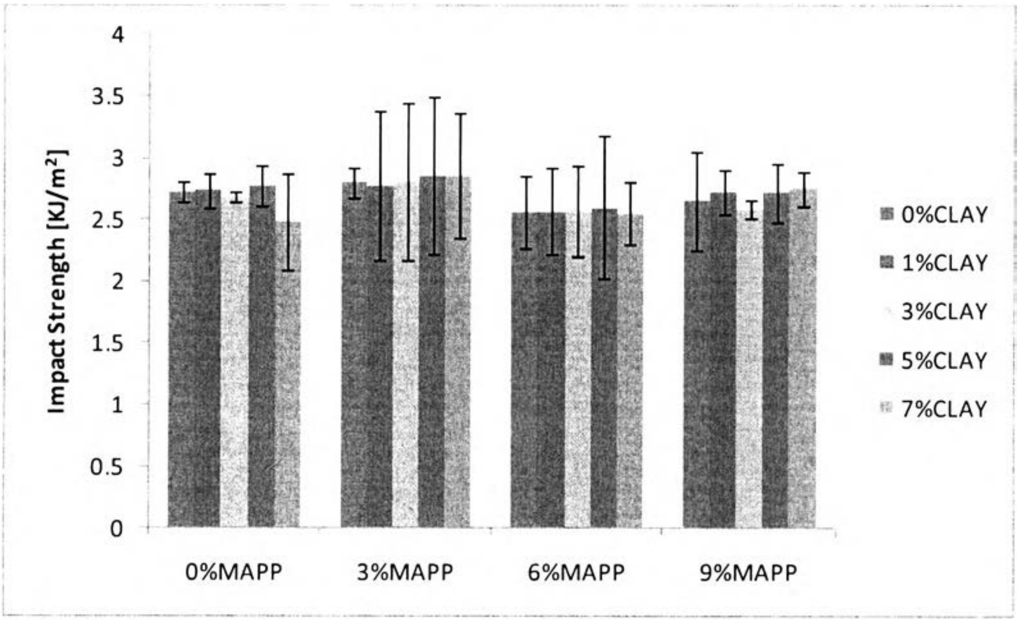


Figure 4.7 Impact strength of WPC at MAPP content of 0%, 3%, 6% and 9% w/w at different nanoclay levels.

The effect of nanoclay incorporation on the impact strength is shown in figure 4.7. The addition of nanoclay at every content showed insignificant effect to impact strength. At the higher of MAPP levels, the nanoclay incorporation also had a slight effect on impact strength. Although the nanoclay is a rigid particle, the low content of nanoclay compared to wood flour levels resulted in unnoticeable change in improvement on impact strength.

4.3 Thermal Property

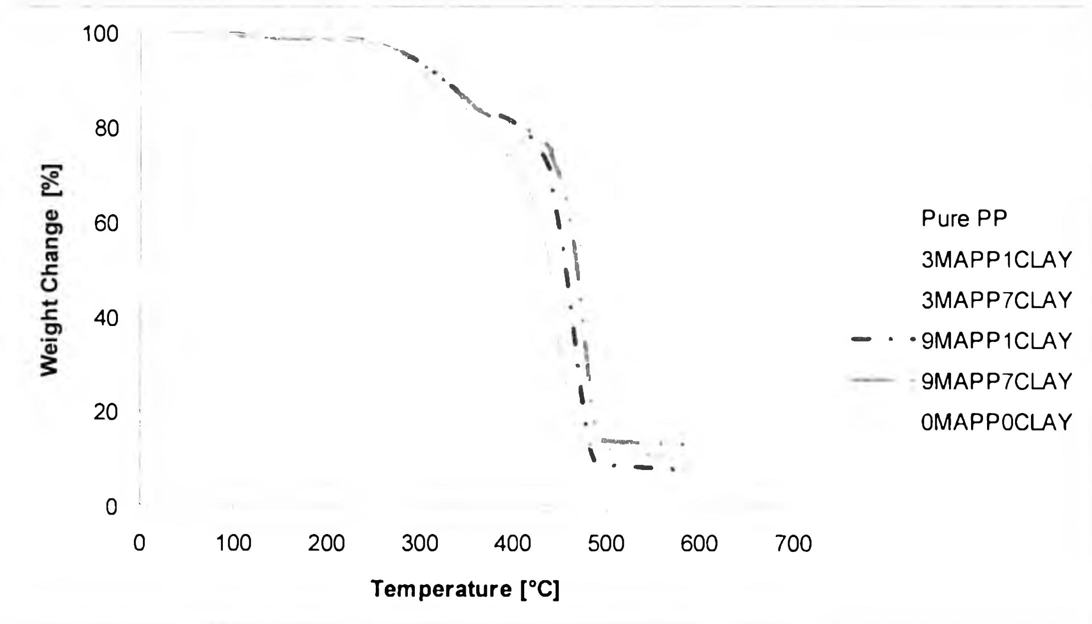


Figure 4.8 Effect of nanoclay and MAPP content on thermal stability of nanoclay incorporated wood plastic composites.

From figure 4.8, neat PP has a degradation temperature at 350°C and WPC without MAPP and nanoclay shows two step degradation temperature at 350°C and 450°C. The residue of 15.1% was the results of wood flour carbonization. The incorporation of nanoclay increased the decomposition temperature of WPC. The increment of decomposition temperature was attributed to the hindered diffusion, or the barrier effect, of volatile decomposition products caused by the dispersed clay particles in the PP matrix. The barrier effect obstructed oxygen diffusion in the specimens and made them more difficult to burn. Consequently, at the same content of MAPP, more nanoclay addition resulted in the improvement of thermal stability. On the other hand, at the same content of nanoclay, the increase of MAPP levels resulted in the reduction on thermal stability. This is due to low decomposition of the MAPP which reduce the thermal stability of the composites. Therefore, it could be concluded that the addition of naoclay has highly effective in thermal improvement, but the increase of MAPP resulted in the decline in thermal stability.

4.4 XRD Patterns of WPC

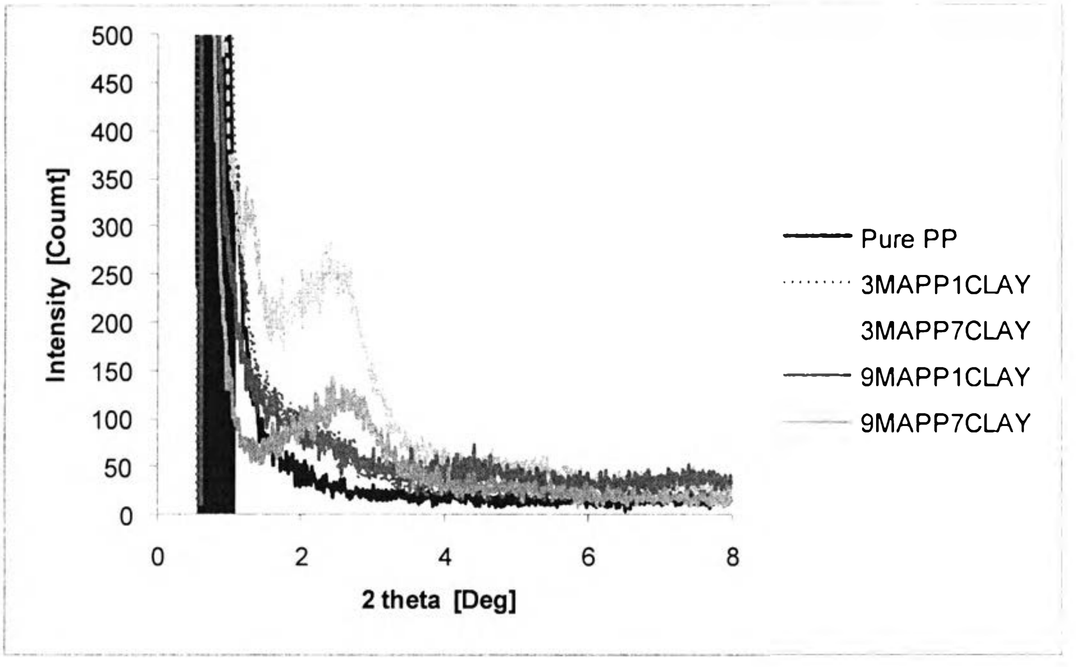


Figure 4.9 XRD patterns of WPC at different CTAB levels and Nanoclay content.

Neat PP showed no peak due to the PP crystal would be demonstrated at higher degree. The incorporation of nanaclay at 1% w/w resulted in complete exfoliation at both 3% and 9% w/w of CTAB content. However, the higher content of nanoclay at 7% w/w results in mixture of exfoliation and intercalation in the matrix. Even though, the MAPP was more added, it could not exfoliate the nanoclay any further. This phenomenon could explain the decline of tensile and flexural strength when more nanoclay was incorporated. The reason for incomplete exfoliation might come from the processing at which the wood flour and nanoclay were added at the same time. The viscosity of the melt compound might obstruct the penetration of polymer chain into the nanoclay gallery and prevent it exfoliation.

4.5 Water Absorption

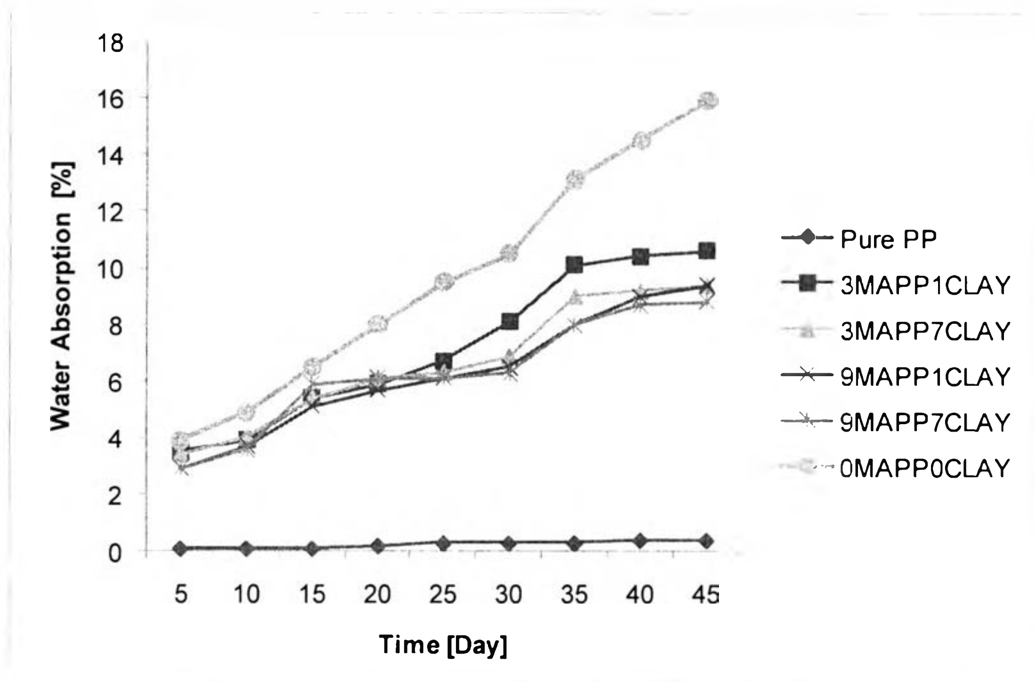


Figure 4.10 Effect of nanoclay and MAPP content on water uptakes of nanoclay incorporated wood plastic composites.

Neat PP showed very low water absorption which due to the hydrophobic property. The addition of wood flour significantly increased the water uptakes since wood was hydrophilic. The water uptakes increased quickly on the first days. This water absorption phenomenon was likely occurred at the surface of the composites. The WPC without nanoclay and MAPP showed high water uptakes and continued to absorb more water when the time increased. Compared to the specimens which nanoclay and MAPP were added, the water absorption increased quickly on the first days of the experiment and then level off. The incorporation of nanoclay decreased the water absorption due to the barrier effect. The dispersion of nanoclay created longer water diffusion paths and slowed water penetration. The higher nanoclay content resulted in less water absorption. The addition of MAPP also took part in prevent the water diffused into the specimens by coating the wood surface and made the water more difficult to penetrate the specimens surface. It could be concluded that both nanoclay and MAPP had highly efficient in prevention of water uptakes and slow the water penetration into the specimens.