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Preparation and Properties of Chlorinated Epoxidised Natural Rubber Latex and Its Latex-Based Adhesive

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Chlorinated epoxidised natural rubber (CENR) was synthesised using epoxidised natural rubber (ENR) in its latex state with an in-situ *chloride ion generating substance. The influences of the molar ratios of sodium hypochlorite/sodium chloride (NaOCl/NaCl), pH and the concentration of the NaOCl/NaCl, and reaction time on the level of chlorine contents in the CENR molecules were investigated. FTIR observation showed the presence of a C-Cl band in the rubber structure upon chlorination of the ENR by mixing it with NaOCl and NaCl. The thermogravimetric analysis proved that chlorination provided the CENR with superior thermal stability than that of the ENR. The CENR latex was then formulated and compounded to prepare a latex-based adhesive. It was found that crosslink reactions generated by different vulcanisation systems caused different adhesive strengths in terms of shear strength and cleavage peel strength. Furthermore, the adhesive exhibited higher shear strength than the commercial grade adhesives (*i.e.*, Contact® and Dragon®) where comparable peel strengths were obtained. However, both properties were relatively lower when compared with Diabond®.*

Keywords: chlorinated epoxidised natural rubber; sodium hypochlorite; sodium chloride; latex-based adhesive

Improvements in the thermal and flame properties of natural rubber can be done by blending natural rubber with other halogens containing polymers such as chlorinated polyethylene and chlosulphonated polyethylene[1–3] by adding a heat stabiliser or halogenated free flame retardant agent[4,5] and by modification of natural rubber molecules[6,7].

Chlorinated natural rubber (CNR) has been synthesised and commercially exploited due to its excellent properties such as acid proof, alkali proof, corrosion resistance and being thermally stable[6,8]. In the past, the CNR was generally prepared using the solution method by blowing chlorine gas into the rubber solution[7,9]. However, this method encountered serious technical problems as it is expensive and may be hazardous and harmful to the environment due to the use of volatilised solvent and chlorine gas[10,11]. To counter these problems, a number of attempts have been made to prepare CNR using natural rubber latex but chlorine gas has still been the main substance used for chlorination[12–16]. Another efficient approach for the preparation of CNR is to employ *in-situ* materials which

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generate chlorine from acidified hypochlorite solution[17]. This technique is easily carried out by immersing a natural rubber sheet in a mixture of sodium hypochlorite/hydrochloric acid and distilled water at room temperature. Chlorination on the surface of the natural rubber sheet improves the frictional resistance of the surface of natural rubber gloves[18,19]. Furthermore, this technique had been used to promote the adhesion of CNR to polar rubber, for example nitrile rubber[20]. However, the application of this method using acidified hypochlorite solution is limited because chlorination is formed only on the surface of the rubber.

Epoxidised natural rubber (ENR) is another important type of modified NR which is commercially available. The ENR has excellent strength, moderately acquired solvent and oil resistance, and gas impermeability properties due to its epoxide contents[21]. Generally, ENR, like NR is still poor in ageing, thermal and flame properties. In order to improve these properties, hydrogenation and halogenation has been applied to the ENR[22,23]. Halogenated ENR, for example in the case of chlorinated ENR (ClENR) and brominated ENR (BrENR) possess a good adhesion property to metal, glass or ceramics and an excellent thermal property as claimed by Cataldo[9].

The use of NR or ENR latex instead of rubber solution avoids the purification step, leading to low production costs and increased safety. Furthermore, the combined use of sodium hypochlorite and sodium chloride has not yet been applied to the preparation of chlorinated ENR in a latex state. Therefore, in this work, chlorinated epoxidised natural rubber was prepared by the *in-situ* chlorine generation technique based on the reaction of sodium hypochlorite and sodium chloride with ENR in a latex state. The CENR latex was then formulated to prepare an adhesive for wood applications.

EXPERIMENTAL

Materials

High ammonium natural rubber latex having dry rubber content (DRC) of approximately 60% was manufactured by Yala Latex Co., Yala, Thailand. Amphitol 55AB surfactant used as a latex stabiliser during chlorination was manufactured by Kao Industrial (Thailand) Co. Ltd., Thailand. Sodium hypochlorite (NaOCl) and sodium chloride (NaCl) were used as chlorine ion generated reactants and were manufactured by Tianjin Xinze Fine Chemical Co. Ltd., China and Ajax Finechem Pty. Ltd., New Zealand, respectively. The hydrochloric acid used to acidify the latex to an assigned pH value was manufactured by Fisher Scientific Co. Ltd., United Kingdom. All the chemicals used in the preparation of the CENR latex-based adhesive are shown in *Table 1*. The commercial solvent based adhesives, Contact®, Dragon® and Diabond® were used for purposes of comparison. The first two materials are general purpose adhesives manufactured by Tandra MKT Ltd. and Pathanachai Support Co. Ltd., Thailand, respectively. The latter is a chloroprene based adhesive manufactured by Kishimoto Sangyo (HK) Co. Ltd., Japan.

Preparation of Low Molecular Weight Epoxidised Natural Rubber Latex

Low molecular weight epoxidised natural rubber (ENR) latex was synthesised by chain-scission parallel with the epoxidation technique according to the procedures described elsewhere[24]. The high ammonia concentration NR latex with a DRC of 60% was firstly diluted with distilled water to a DRC of 20% and then mixed with formic acid and hydrogen peroxide to obtain epoxidised natural rubber. The reaction temperature was set at 50ºC for 2 hours. The reaction

TABLE 1. CHEMICALS USED IN LATEX ADHESIVE FORMULATION AND THEIR SUPPLIERS

Chemicals	Suppliers
C9 petroleum resin tackifier	Zhongde Petroleum Resins Co. Ltd., China
Carboxy methyl cellulose (CMC)	China National Chemical Construction Co. Ltd., China
Wingstay L®	Eliokm Inc., USA
Sulphur	Ciech S.A. Co. Ltd., Poland
ZnO	Global Chemical Co. Ltd., Thailand
ZDEC	Bayer Co. Ltd., Germany
Phenolic resin (HRJ-10518)	Schenectady International Inc., USA
Stanous dichloride	Schenectady International Inc., USA
Phthalic anhydride	Fluka Chemical, Switzerland
Imidazole	Fluka Chemical, Switzerland

mixture was then immediately cooled down to room temperature and mixed with sodium nitrite solution (2% w/w). The mixture was continuously stirred for another 24 hours. The ENR latex was coagulated using methanol and dried in a hot air oven at 40ºC for 48 hours. A solution of the ENR in toluene was then prepared and its viscosity determined by using the Ubbelodhe viscometer. The viscosity average molecular weight (M_v) of the ENR was calculated using a Y-intercept from the plot of the viscosity data[25]. Also, the level of epoxide groups in the ENR molecules was estimated by the FTIR method as previously described elsewhere[24,26].

Preparation of Chlorinated Low Molecular Weight Epoxidised Natural Rubber (CENR)

The ENR latex with a DRC of approximately 20% was used to prepare CENR latex. The ENR was stabilised by 7 wt% of Amphitol 55AB, a cocamidopropyl betaine based amphoteric surfactant and then transferred into a reaction kettle. A solution consisting of a mixture of sodium hypochlorite and sodium chloride (NaOCl/NaCl) was slowly added to the latex. The reaction mixture was then continuously stirred at 30ºC under an N_2 atmosphere. The three parameters investigated in this work are as follows:

- The influence of the molar ratios of NaOCl/NaCl.

  Various molar ratios of NaOCl/NaCl were studied at 1.0:0, 1.0:1.0, 1.0:2.5, 1.0:5.0, 0:1.0, 2.5:1.0 and 5.0:1.0 with a reaction time of 6 h at 30ºC under an N_2 atmosphere. After the reaction, the latex was coagulated using methanol and was washed many times with distilled water to remove the acid and surfactant, then dried in a hot air oven at 40ºC for 12 hours. FTIR was then used to characterise the molecular structure of the CENR obtained. Further, a thermogravimetric analyser (TGA) was used to investigate the thermal degradation of the CENR and the chlorine content was quantified by the X-ray fluorescence (XRF) technique.

- The effect of pH and concentration of the NaOCl/NaCl.

  In this study, the molar ratio of NaOCl/NaCl was fixed at 2.5:1.0. The reaction was carried at 30ºC under an N_2 atmosphere for 6 hours. Three different treatments were then performed, as follows:

I. Control: The typical chlorination reaction without pH adjustment (pH = 3.5).
II. Treatment no. 1: The pH of the ENR latex was adjusted using hydrochloric solution from 3.5 to 1.0 prior to chlorination.
III. Treatment no. 2: The pH of the ENR latex was adjusted according to treatment no. 1 but the amount of NaOCl/NaCl was two times higher than that in treatment no. 1.

After the chlorination, the treated latices were sampled and the chlorine content was quantified by the XRF technique.

- The effect of reaction time.

  The CENR latex was prepared using conditions of Treatment no. 2. The reaction was performed with reaction times of 1, 3, 6, 9 and 12 hours. The chlorine content was then quantified by the XRF technique.

Preparation of the CENR Latex-based Adhesives

CENR latex having the highest chlorine content was selected to be compounded with various chemicals to produce the adhesive. Each formulation had a final total solid content (TSC) and viscosity of approximately 40% and 2,200 cps, respectively. In this work, the influence of four types of vulcanisation systems, conventional sulphur vulcanisation system (CV), efficient sulphur vulcanisation system (EV), phthalic anhydride (PA) imidazole and phenolic cured system on shear strength and cleavage peel strength of the CENR latex-based adhesive on wood samples was investigated according to *ASTM D-2339* and *ASTM D-3807*, respectively. The vulcanising agents and chemicals used to prepare the adhesives are summarised in *Table 2*. In addition, the adhesion performance of the adhesive prepared in this work was compared with three commercial adhesives, Contact®, Dragon® and Diabond®.

Characterisation and Testing of Adhesive Strength

Infrared spectroscopy. Thin films of the ENR and CENR were prepared by spreading the latex on a glass mould. After evaporation and washing the film a number of times with distilled water, it was dried in a hot air oven at 40ºC for 12 hours. A Fourier transform infrared spectrophotometer; FTIR (model Omnic ESP Magna-IR 560, Nicolet Instrument Corp., Madison, WI, USA) was used to characterise the molecular structures of the ENR and CENR using the mid IR region with wave numbers from 4000 to 400 cm^{-1}. The level of the epoxide groups in the ENR and CENR was evaluated from the characteristic peaks at 835 and 870 cm^{-1} in the IR spectra according to the well known equation[21].

$$A_r = \frac{a_{870}}{a_{836} + a_{870}} \quad \ldots 1$$

Where, a_{870} and a_{836} are the absorbance values at the wave numbers of 870 cm^{-1} and 836 cm^{-1} due to *cis*-epoxy and C-H out of plane bending respectively.

Thermogravimetric Analysis (TGA). The thermal stability of the ENR and CENR prepared was studied using a TA instrument (TGA 7, Perkin Elmer Ltd, USA). Solid samples were prepared by coagulating the ENR and CENR latices with methanol, washing them several times with distilled water and drying them in a hot air oven at 40ºC for 24 hours. The samples were later characterised by TGA in temperature range of 50 to 800ºC with a heating rate of 10ºC/min under an N_2 atmosphere.

TABLE 2. FORMULATION OF THE CENR LATEX-BASED ADHESIVE WITH VARIOUS VULCANISATION SYSTEMS

Chemicals	Quantities (p.h.r.)			
	CV	EV	Phenolic	PA/Imidazole
CENR latex	100	100	100	100
50% C9 Petroleum resin dispersion	30.0	30.0	30.0	30.0
10% CMC solution (in water)	5.0	5.0	5.0	5.0
20% Potassium oleate	3.0	3.0	3.0	3.0
50% Wingstay L® dispersion	1.5	1.5	1.5	1.5
50% ZnO dispersion	10.0	10.0	10.0	10.0
50% Sulphur dispersion	10.0	5.0	-	-
50% ZDEC dispersion	0.75	10.0	-	-
50% HRJ dispersion	-	-	4.5	-
Stanous dichloride	-	-	0.7	-
Phthalic anhydride	-	-	-	5.0
Imidazole	-	-	-	1.0

X-ray Fluorescence Spectrometry. The chlorine content of the CENR was semi-quantitatively analysed by an X-ray fluorescence spectrometer; XRF (model PW2400, Philips, Eindhoven, The Netherlands). The instrument was equipped with a Rhodium anode X-ray tube with a stabilised high voltage of 30 kV and an electron current of 80 mA, which is the optimum parameter for the determination of Cl atoms.

Testing of Adhesive Strength. The shear and cleavage peel strengths of the adhesives were performed according to the *ASTM D-2339* and *ASTM D-3807*, respectively. Firstly, a latex-based adhesive was applied on surface of wood samples by control % weight of the adhesive. Test samples were then dried in a hot air oven at 80ºC for 24 h in order to evaporate the water and vulcanise. The bondline thickness after drying was approximately 0.10 mm. Adhesive strength was determined using a Hounsfield tensometer (model H 10 KS, Hounsfield Test Equipment Co., Ltd., Raydon, UK). At least five shear and peel tests were carried out for each type of adhesive to determine the reproducibility of the test results.

RESULTS AND DISCUSSION

The Preparation of Low Molecular Weight ENR and CENR

The average viscosity molecular weight (M_v) of ENR synthesised by chain-scission parallel with epoxidation was measured. *Figure 1* shows the plot of the reduced viscosity (η_{sp}/c) and inherent viscosity ($\ln \eta_r/c$) as a function of the ENR solution concentration. It was found that the M_v of the ENR synthesised in this work was approximately 178 000 g/mol. According to the FTIR observation, it was found that the level of epoxide groups in the ENR molecules was approximately 30 mol %. (discussed in detail in the next section). Therefore, this type of rubber was defined as low molecular weight epoxidised natural rubber with 30 mol % epoxide (ENR 30).

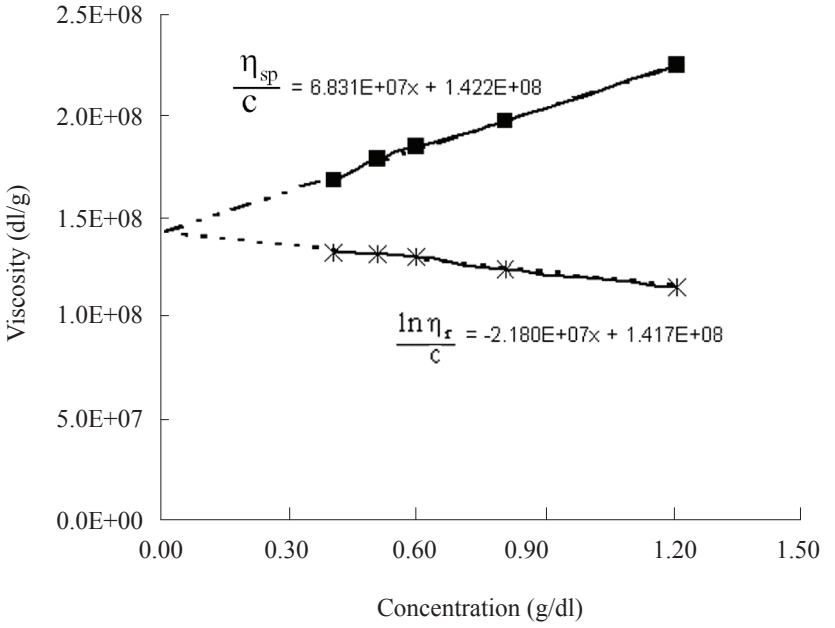


Figure 1. Variation of viscosity for ENR 30 solution as a function of concentration.

Chlorination of the ENR 30 was then carried out using *in-situ* generated chlorine from a reaction of NaOCl and NaCl. Three main parameters were experimentally designed in this study.

The influence of the mole ratios of NaOCl/NaCl. The chlorine contents in the CENR molecules prepared using various molar ratios of NaOCl/NaCl were analysed by the XRF technique and the results are shown in *Figure 2*. This shows that increasing the concentration of NaOCl at a fixed concentration of NaCl of 1 mole or holding the concentration of NaOCl constant and increasing the concentration of NaCl, both caused an abrupt increase in the chlorine content. However, when the mixture had a higher concentration of NaOCl, it seemed to give a higher chlorination level than a higher concentration of NaCl. The highest chlorine content in the CENR was achieved at a molar ratio of NaOCl/NaCl of 2.5:1.0.

The FTIR technique was used to measure chemical structure and chlorine content of the CENR. *Figure 3* shows the FTIR spectra of the ENR 30 and the selective CENR which was prepared using molar ratio of NaOCl/NaCl of 2.5:1.0. The main characteristic peaks observed in the spectrum are summarised in *Table 3*. It can be seen that the CENR exhibited significant characteristic peaks similar to those of the ENR 30. However, a strong intensity peak at a wave number of 756 cm^{-1} in the case of CENR was clearly seen, which was attributed to C-Cl stretching vibration. This confirmed that chlorination of the ENR 30 had been affected by adding the mixture of NaOCl/NaCl. Further, the ratio of the absorbance values at 756 cm^{-1} (C-Cl stretching) and 1660 cm^{-1} (C=C stretching) can be used to imply the degree of chlorination in the CENR. Values of absorbance ratio are tabulated in *Table 4*. It was found that the absorbance ratio increased with increasing the molar ratio of NaOCl/

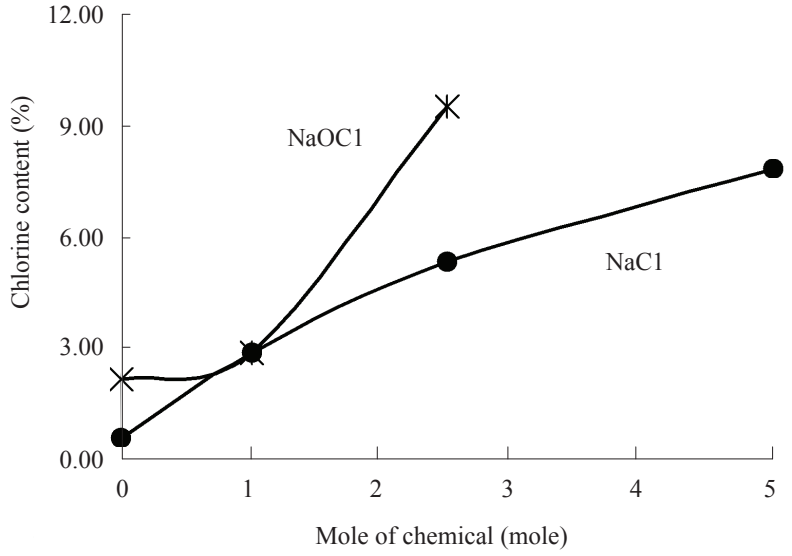


Figure 2. Effect of molar ratios of the NaOCl/NaCl mixture on percentage of chlorine contents of the CENR; ✳ represents the NaOCl/NaCl mixture with constant amount of NaCl (1 mole), whereas ● is the NaOCl/NaCl mixture with fixed amount of NaOCl (1 mole).

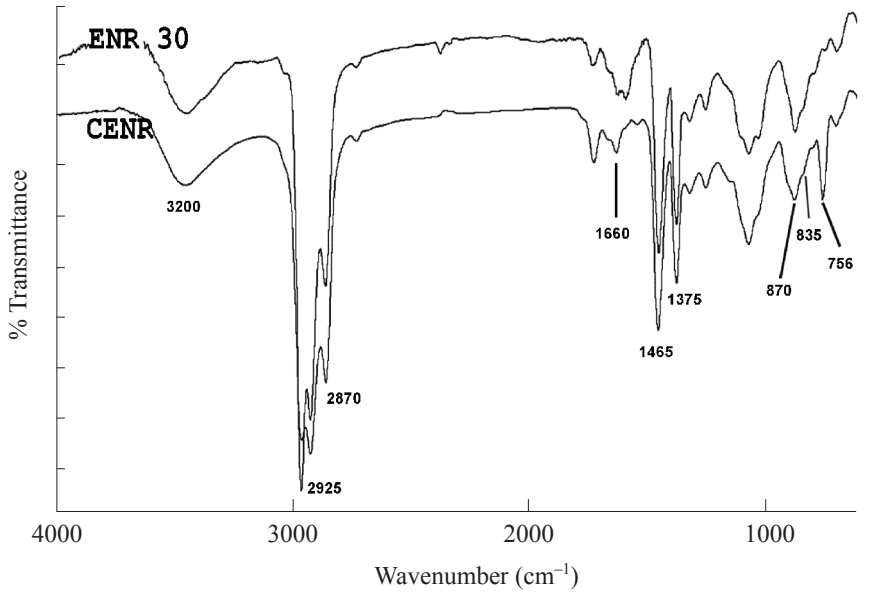


Figure 3. FTIR spectra of ENR 30 and CENR.

TABLE 3. CHARACTERISTICS OF IR ABSORPTION BANDS OF ENR 30 AND CENR

Functional groups	Wavenumber (cm^{-1})	
	ENR 30	CENR
=CH stretching	3028	3028
C-H stretching of CH_3	2960, 2870	2960,2870
C-H stretching of CH_2	2925, 2850	2925, 2850
C-H bending of CH_3	1375	1375
C-H bending of CH_2	1465	1465
C=C stretching	1660	1660
C-H wagging	835	835
	870	870
C-Cl stretching	-	756
O-H	3200-3400	3200-3400

NaCl. This increase was almost similar to the results from the XRD study which confirmed chlorination of the CENR by the *in-situ* generated chlorine substance.

The reaction scheme of ENR 30 with the NaOCl/NaCl mixture is proposed in *Scheme 1*. Under acidic conditions, the NaOCl can undergo reaction with hydrochloric acid to generate chlorine gas (*Scheme 1(1)*), while NaCl produces the chloride ion (*Scheme 1(2)*). Chlorine gas and chloride ion in the reaction then actively react with the ENR molecules. The reaction was believed to have taken place *via* the opening of oxirane rings in the epoxide units (*Scheme 1(4)*)[27] and/or *via* unsaturated sites in isoprene units (*Scheme 1(5-6)*). The former reaction, however, was improbably due to the level of epoxide groups (*Table 4*) in the CENR molecules that still remained at approximately the same level (30 mol %) as that of the ENR 30. It is also interesting to note that the absorption peak of the CENR at 1660 cm^{-1} corresponding to the C=C bond stretching, after recalculation to eliminate an error of test sample preparation, seemed to slightly decrease with increasing the molar ratio of NaOCl/NaCl. This may be ascribed to the chlorination that occurred *via* double bonds along the ENR 30 molecules instead of oxirane rings, as proposed in *Scheme 1*.

TGA and DTG thermograms of ENR 30 and CENR with the highest chlorine content evaluated under an N_2 atmosphere are shown in *Figure 4*. The TGA thermogram of CENR showed a two-step decrease in weight% which indicated double degradation stages, whereas the thermogram of the ENR showed only a one-step decrease. The first degradation stage of the CENR was observed at 268ºC (T_{max}), attributable to the release of chlorine molecules through a dehydrochlorination reaction. The second degradation stage observed at 432ºC was due to decomposition of the rubber hydrocarbon[2]. However, in contrast to the CENR, the ENR 30 showed only a single degradation stage at 399ºC (*Figure 4(b)*). From these results, it is clear that chlorination using *in-situ* generated chloride ions and chlorine gas caused the degradation of the rubber hydrocarbon to occur at a higher temperature and hence resulted in better thermal stability[6,28].

The effect of pH and the concentration of NaOCl/NaCl. The influence of pH and the

TABLE 4. INFLUENCE OF MOLAR RATIO OF NaOCl/NaCl ON EPOXIDE LEVEL AND CHLORINE CONTENT OF CENR

Molar ratio of NaOCl/NaCl	Epoxide level (%)	Absorbance value of C-Cl stretching (1)	Absorbance value of C=C stretching (2)	Value of C=C stretching (2)/(1) (recalculation)	Absorbance ratio (C-Cl / C=C)	Cl content (%) from XRD
1.0 : 0	30	1.04	20.86	20.06	0.05	0.54
1.0 : 1.0	31	4.62	19.24	4.16	0.24	2.88
1.0 : 2.5	31	10.44	21.31	2.04	0.49	5.32
1.0 : 5.0	30	10.74	15.12	1.41	0.71	7.80
0 : 1.0	30	3.64	24.29	6.67	0.15	2.16
2.5 : 1.0	29	19.17	22.03	1.12	0.87	9.52
5.0 : 1.0	-	-	-	-	-	Coagulation

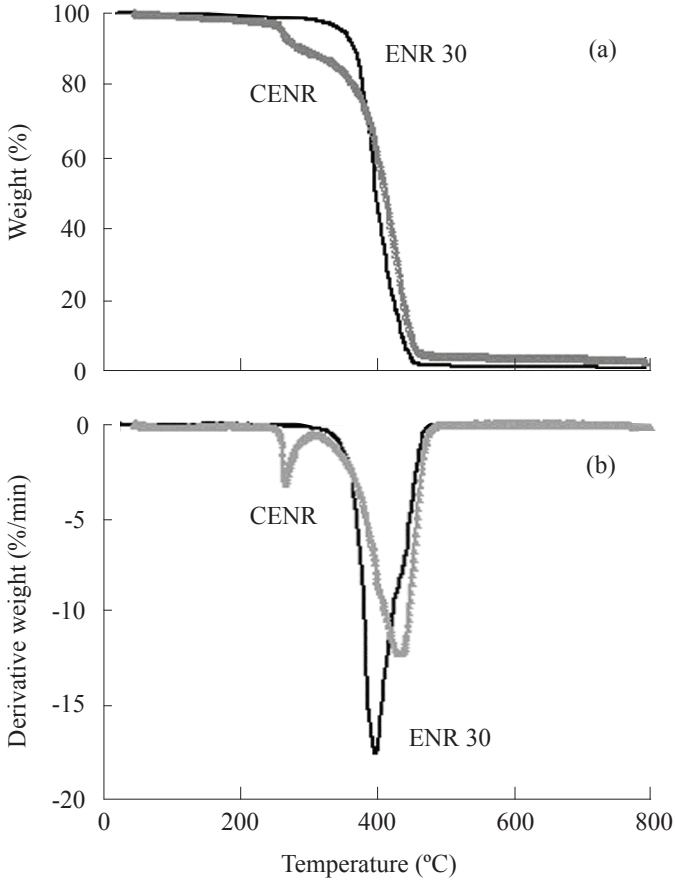
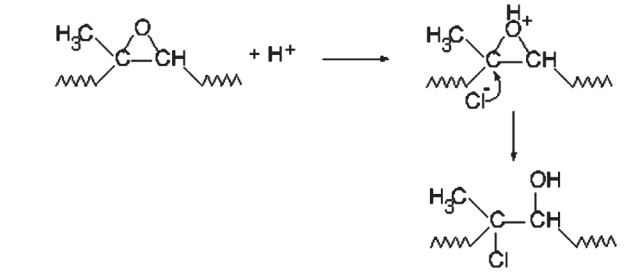


Figure 4. TGA thermogram of ENR 30 and CENR.

$$NaOC1 + 2HC1 \rightarrow C1_2 + H_2O + NaC1 \quad \ldots 1$$

$$NaC1 \rightarrow Na^+ + C1^- \quad \ldots 2$$

$$HC1 \rightarrow H^+ + C1^- \quad \ldots 3$$



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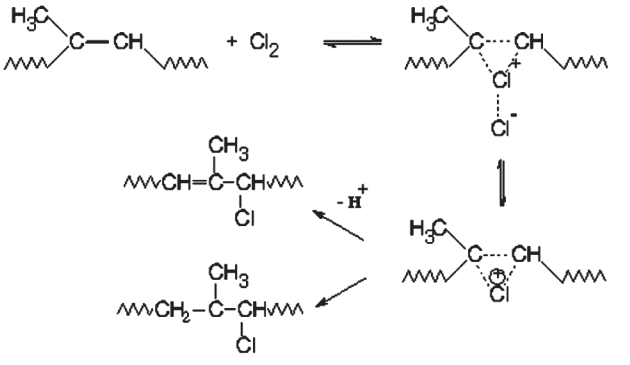

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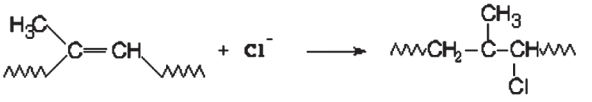

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Scheme 1. Schematic diagram of chlorination of the ENR 30 latex in the presence of NaOCl/NaCl mixture.

concentration of the NaOCl/NaCl mixture on the level of chlorine in the CENR was investigated using different treatments as described previously. *Figure 5* shows the chlorine contents in the CENR latex as a function of the chlorination conditions. Decreasing the pH of the initial ENR latex from 3.5 to 1.0 before adding the mixture of NaOCl/NaCl (*i.e.*, Treatment No. 1) caused a slight increase in the chlorine content of the CENR. However, combining the same pH adjustment as in Treatment no. 1 with double the increase in concentration of NaOCl/NaCl (*i.e.*, Treatment no. 2) significantly increased the chlorine contents (to approximately 32%). This was due to the generation of abundant chloride ions in the mixture under the strongly acidic conditions of Treatment no. 2. Under these conditions, chlorination occurred rapidly *via* the double bonds as discussed previously,

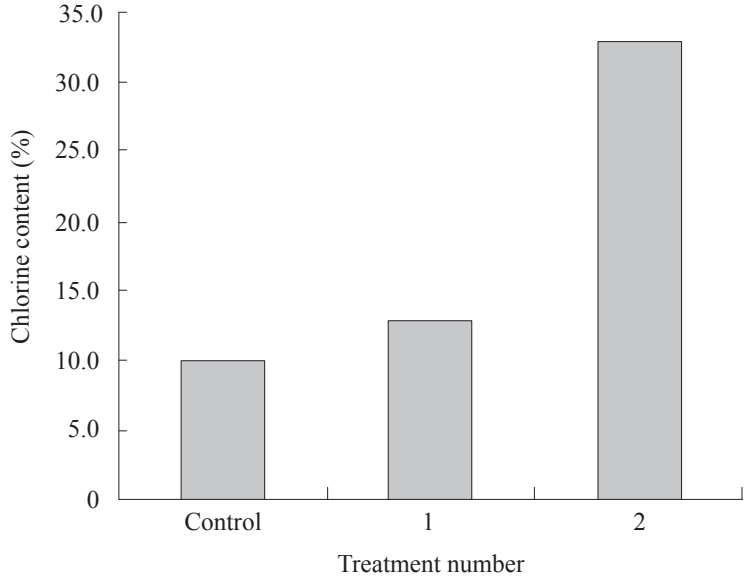


Figure 5. Percentage of chlorine contents in CENR latex with various chlorination conditions.

yielding a product with higher chlorine content.

The effect of reaction time. The effect of reaction time on the chlorination level in the CENR molecules was investigated under Treatment no. 2 and the result is shown in *Figure 6*. The chlorine content in the CENR molecules increased as the reaction time was increased to 9 h after which the chlorine content decreased. This increasing trend is due to a higher amount of chloride ions being generated with a longer reaction time, thereby promoting the chlorination of the ENR molecules.

Properties of Adhesive Based on CENR Latex

The influence of vulcanisation systems. CENR latex with the highest chlorine content of approximately 32% was used as the raw material for the preparation of CENR adhesives. The influence of different types of vulcanisation systems on the adhesion properties of the adhesives (*i.e*., shear strength and cleavage peel strength) on wood substrates was investigated.

Figures 7 and *8* show the shear and cleavage peel strength of CENR adhesives manufactured using various vulcanisation systems. The results show that the application of different curing systems resulted in different adhesion strengths in the CENR latex-based adhesives. Among the four types of curing systems used (CV, EV, PA/Imidazole and Phenolic), sulphur-based curing systems (*i.e*., CV and EV) gave higher shear and cleavage peel strength than the other two curing systems.

The inferior adhesion properties resulting from the use of the PA/Imidazole system might be attributable to the crosslinking

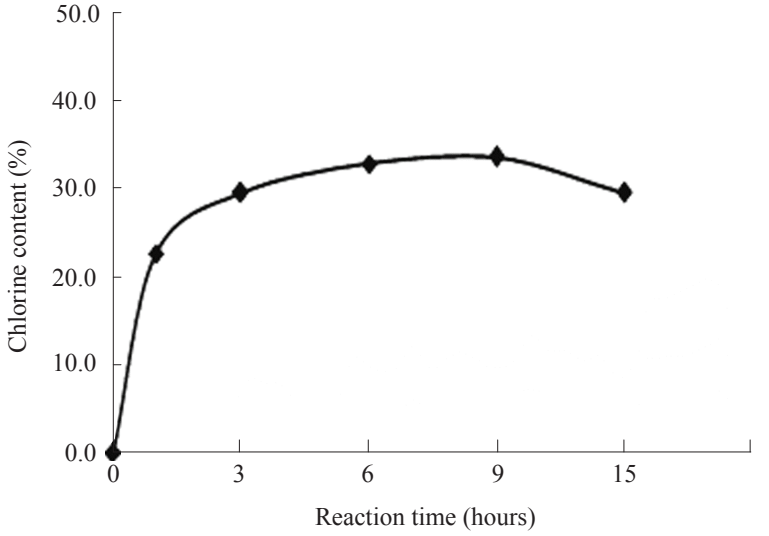


Figure 6. Percentage of chlorine contents measured by XRD with various reaction times.

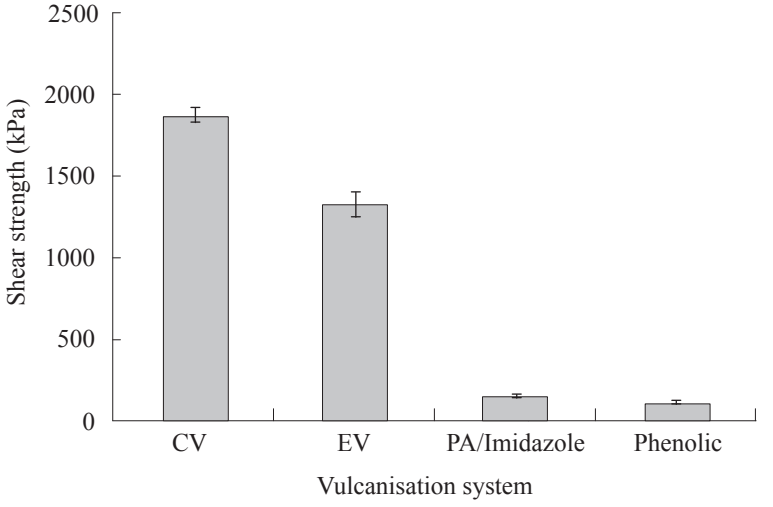


Figure 7. Shear strength of CENR latex-based adhesive with various vulcanisation systems.

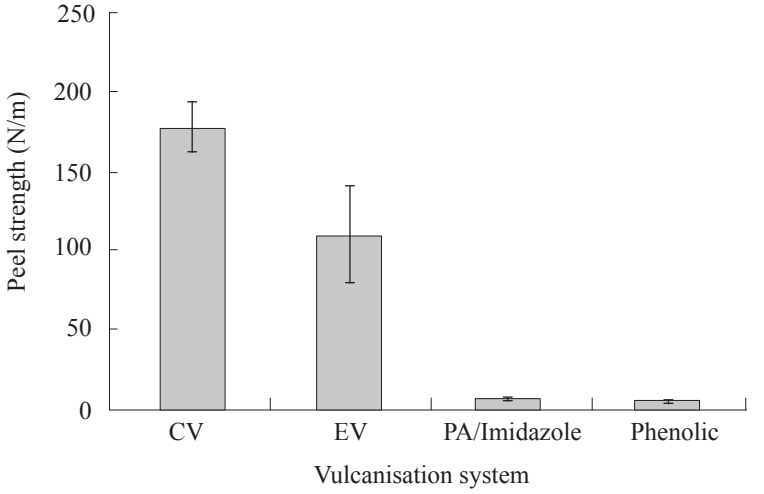
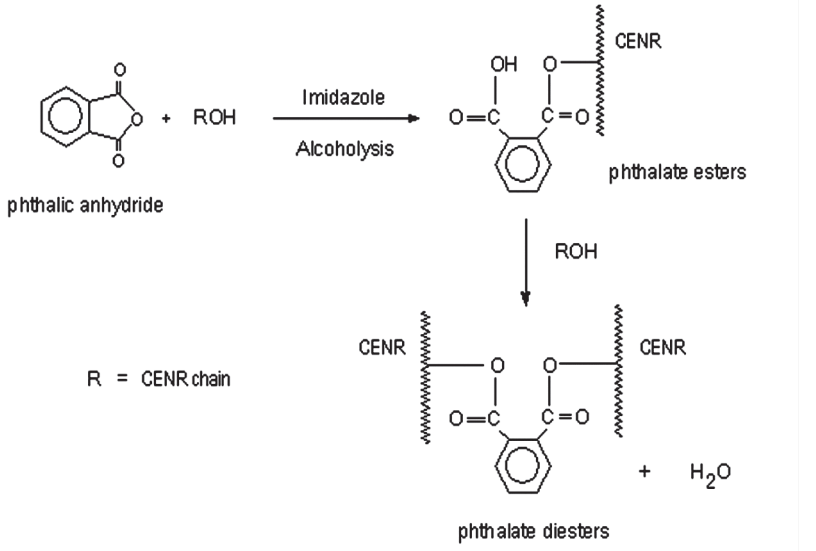


Figure 8. Cleavage peel strength of CENR latex-based adhesive with various vulcanisation systems.



Scheme 2. Proposed reaction of the CENR with phthalic anhydride as crosslink agent[29].

TABLE 5. ADHESIVE STRENGTH OF THE CENR ADHESIVE IN COMPARISON WITH COMMERCIAL ADHESIVES

Type of adhesive	Total Solid Content (%)	Viscosity (cps.)	Shear strength (KPa)	Peel strength (N/In.)
CENR[a]	44.7	2073.7	1876.2	178.2
Contact®	40.1	8146.8	510.0	227.5
Dragon®	39.8	8759.4	240.0	205.6
Diabond®	51.1	70000.0	2540.0	387.1

CENR[a] – cased adhesive was cured by conventional sulphur curing system.

mechanism, proposed in reaction *Scheme 2*; that is, the CENR reacted with phthalic anhydride and phthalate esters, and phthalate diesters were formed during the curing reaction. These substances might behave as a phthalate plasticiser which improved the molecular movement of rubber chains and hence reduced the strength of the adhesive[29].

In the case of the phenolic curing system, a general crosslink mechanism usually involves the presence of an acid catalyst and the relocation of a double bond between the rubber and the phenolic molecules[30]. Even though the phenolic molecules provided a strong cross-link between the rubber molecules, due to the restriction on chain mobility at the crosslink junction, the strength of the phenolic-cured adhesive was reduced. As a result, the phenolic curing system promoted adhesion at the interface with a brittle layer of adhesive. On the other hand, the CV and EV curing systems provided flexible adhesive layers containing sulphur crosslinks which exhibited excellent adhesive strength.

Comparison of Adhesion Performance of CENR Adhesive with Commercial Adhesives

Table 5 shows the adhesive strength in terms of shear strength and cleavage peel strength of the conventional sulphur cured CENR adhesive compared with three commercial synthetic adhesives, Contact®, Dragon® and Diabond®. The results from *Table 5* show that the CENR adhesive derived from the CV curing system provided superior shear strength to those of Contact® and Dragon® with comparable cleavage peel strength. However, the adhesion strength of the CENR adhesive was still inferior to that of Diabond®, which is a chloroprene based adhesive. This may be attributed to Diabond® containing a very high total solid content and viscosity. Based on similar amounts of adhesive (based on solid content) applied to wood samples, Diabond® exhibited superior strength to that of the CENR adhesive as well as those of other adhesives.

CONCLUSION

The chlorination of ENR 30 was successfully conducted using a mixture of NaOCl/NaCl. The influence of the molar ratios of NaOCl/NaCl, pH and the total concentration of NaOCl/NaCl as well as reaction times on the chlorine content of the CENR was studied. It was found that these factors strongly affected the chlorine content in the CENR molecules. The presence of chlorine in the rubber molecules yielded a rubber with better thermal stability. Furthermore, the CENR was used to prepare latex-based adhesives using

different vulcanisation systems. The results presented in this study suggest that CV cured CENR adhesive could be used as a substitute for commercially available synthetic rubber adhesives such as Contact® and Dragon®.

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