CHAPTER 5

RESULTS

5.1 Result of Determination of Molasses Content

The experimental results of this part are shown in Table 5.1 and Figure 5.1 - 5.3. Density decrease as the percentage of molasses content increase, but begin to increase when molasses content is 60%. Compressive strength of polyurethane foams are shown in Figure 5.2, the maximum value is obtained at % molasses of 50, but when % molasses increases to 60 the foam became brittle and rupture at about 4.67% deformation. Drift and set increase with molasses content, then begin to decrease when % molasses is 35.

Table 5.1 Mechanical properties of polyurethane for various percentage of molasses

Molasses (%)	Density (ρ) (g/cm^3)	Compressive strength (σ) at 10% deformation (N/mm^2)	σ / ρ	Compressive strength at 50% deflection (N/mm^2)	% Drift	% Set
0	0.2286	0.0139	0.0608	0.0269	6.12	8.55
20	0.1266	0.0606	0.4787	0.1338	40.58	20.45
30	0.1005	0.1279	1.2726	0.1914	43.18	47.17
35	0.0829	0.1186	1.4306	0.1676	16.46	26.18
40	0.0816	0.1096	1.3431	0.1719	14.20	18.03
50	0.0795	0.1243	1.5635	0.1591	12.48	19.73
60	0.1503	0.0295	0.1963	-	-	-

5.2 Result of Determination of Quantity of Husk.

In Table 5.2 - 5.4 and Figure 5.4 - 5.8, the results of various weight percentage of husk at a fixed % molasses of 20, 35 and 50 are obtained. At % molasses of 20 and 35, as the percentage of husk content increases, the density and the compressive strength increase. The result is different at a fixed % molasses of 50, as the percentage of husk content increases, the density of products increase while compressive strength decrease.

Drift and set of products are shown in Figure 5.6 - 5.8.

Table 5.2 Result of determination of quantity of husk at a fixed % molasses of 20

% husk	Density (ρ) (g/cm^3)	Compressive strength (σ) at 10% deformation (N/mm^2)	σ / ρ	Compressive strength at 50% deflection (N/mm^2)	% Drift	% Set
0	0.1266	0.0606	0.4787	0.1338	40.58	20.45
9.09	0.1452	0.1090	0.7507	0.1831	29.29	27.08
16.67	0.1838	0.1210	0.6583	0.2695	27.57	26.53
20.00	0.1996	0.1345	0.6738	0.3670	26.07	20.11

Table 5.3 Result of determination of quantity of husk at a fixed % molasses of 35

% husk	Density (ρ) (g/cm^3)	Compressive strength at 10% deformation (σ) (N/mm^2)	σ/ρ	Compressive strength at 50% deflection (N/mm^2)	% Drift	% Set
0	0.0829	0.1186	1.4306	0.1676	16.46	26.18
3.51	0.0852	0.1220	1.4319	0.1876	15.82	26.02
9.09	0.1013	0.1419	1.4007	0.2843	14.07	25.52
16.67	0.1269	0.1546	1.2183	0.4192	12.78	22.69
20.00	0.1352	0.1817	1.2439	0.5086	11.71	23.73

Table 5.4 Result of determination of quantity of husk at a fixed % molasses of 50

% husk	Density (ρ) (g/cm^3)	Compressive strength at 10% deformation (σ) (N/mm^2)	σ/ρ	Compressive strength at 50% deflection (N/mm^2)	%Drift	%Set
0	0.0795	0.1243	1.5635	0.1591	12.48	19.73
9.09	0.1393	0.1235	0.8866	0.6376	10.69	18.06
16.67	0.1440	0.1143	0.7938	0.6134	5.73	17.08

5.3 Result of Determination of Quantity of Sawdust.

The results of this experiment are shown in Table 5.5 - 5.7 and Figure 5.9 - 5.13. Sawdust renders the same effect as husk on density and compressive strength. At % molasses of 20 and 35, drift and set decrease with increasing sawdust content, then begin to increase while quantity of sawdust increase further.

5.4 Result of Determination of Size of Sawdust.

In Table 5.8 and 5.9, and Figure 5.18 - 5.21, the result of various size of sawdust at a fixed % molasses of 35 and a fixed % sawdust of 10 and 30 are presented respectively. At % sawdust of 10, the smaller size of sawdust gives higher density and compressive strength. At % sawdust of 30, density and compressive strength increase as the size of sawdust decrease, but compressive strength decrease at the size of sawdust of lower than 0.15 mm.

5.5 Comparison of Mechanical Properties between Polyurethane-filled with Husk and Sawdust.

Mechanical properties of product at a fixed % molasses of 20, as shown in Figure 5.16 and 5.17, husk will give higher compressive strength and density than sawdust. The result is different at a fixed % molasses of 35, in Figure 5.14 and 5.15, sawdust will give higher compressive strength and density than husk.

Table 5.5 Result of determination of quantity of sawdust at a fixed % molasses of 20 and fixed size of sawdust of 0.300-0.212 mm.

% sawdust	Density (ρ) (g/cm^3)	Compressive strength at 10% deformation (σ) (N/mm^2)	σ/ρ	Compressive strength at 50% deflection (N/mm^2)	%Drift	%Set
0	0.1266	0.0606	0.4787	0.1338	40.58	20.45
9.09	0.1448	0.0643	0.4441	0.1851	27.89	29.30
16.67	0.1688	0.0873	0.5172	0.1996	25.92	25.04
23.08	0.1847	0.1158	0.6270	0.2573	28.92	22.81
28.57	0.1960	0.2479	1.2648	0.5210	12.82	17.64

Table 5.6 Result of determination of quantity of sawdust at a fixed % molasses of 35 and fixed size of sawdust of 0.300-0.212 mm.

% sawdust	Density (ρ) (g/cm^3)	Compressive strength at 10% deformation (σ) (N/mm^2)	σ/ρ	Compressive strength at 50% deflection (N/mm^2)	%Drift	%Set
0	0.0829	0.1186	1.4306	0.1676	16.46	26.18
3.51	0.1118	0.1650	1.4758	0.3045	16.15	25.27
9.09	0.1241	0.1780	1.4343	0.3475	15.92	24.60
16.67	0.1293	0.2087	1.6141	0.7081	32.72	30.83
23.08	0.1430	0.3030	2.1189	0.9850	23.08	28.42

Table 5.7 Result of determination of quantity of sawdust at a fixed % molasses of 50 and fixed size of sawdust of 0.425-0.300 mm.

% sawdust	Density (ρ) (g/cm^3)	Compressive strength at 10% deformation (σ) (N/mm^2)	σ/ρ	Compressive strength at 50% deflection (N/mm^2)	%Drift	%Set
0	0.0795	0.1243	1.5635	0.1591	12.48	19.73
9.09	0.1400	0.1148	0.8200	0.7332	6.19	19.48

Table 5.8 Result of determination of size of sawdust at a fixed % molasses at 35% and a fixed % sawdust of 9.09

Size (mm.)	Density (g/cm^3)	Compressive strength at 10% deformation (N/mm^2)	Comp./den.
0.425-0.300	0.1077	0.1455	1.3510
0.300-0.212	0.1241	0.1780	1.4343
< 0.15	0.1514	0.3800	2.5099

comp. = Compressive strength at 10% deformation

den. = density

Table 5.9 Result of determination of size of sawdust at a fixed % molasses at 35% and a fixed % sawdust of 23.08

Size (mm.)	Density (g/cm^3)	Compressive strength at 10% deformation (N/mm^2)	Comp./den.
0.600-0.425	0.1313	0.0964	0.7342
0.425-0.300	0.1402	0.3009	2.1462
0.300-0.212	0.143	0.3030	2.1189
0.212-0.150	0.1897	0.7883	4.1555
< 0.15	0.1989	0.1642	0.8255

comp. = Compressive strength at 10% deformation

den. = density

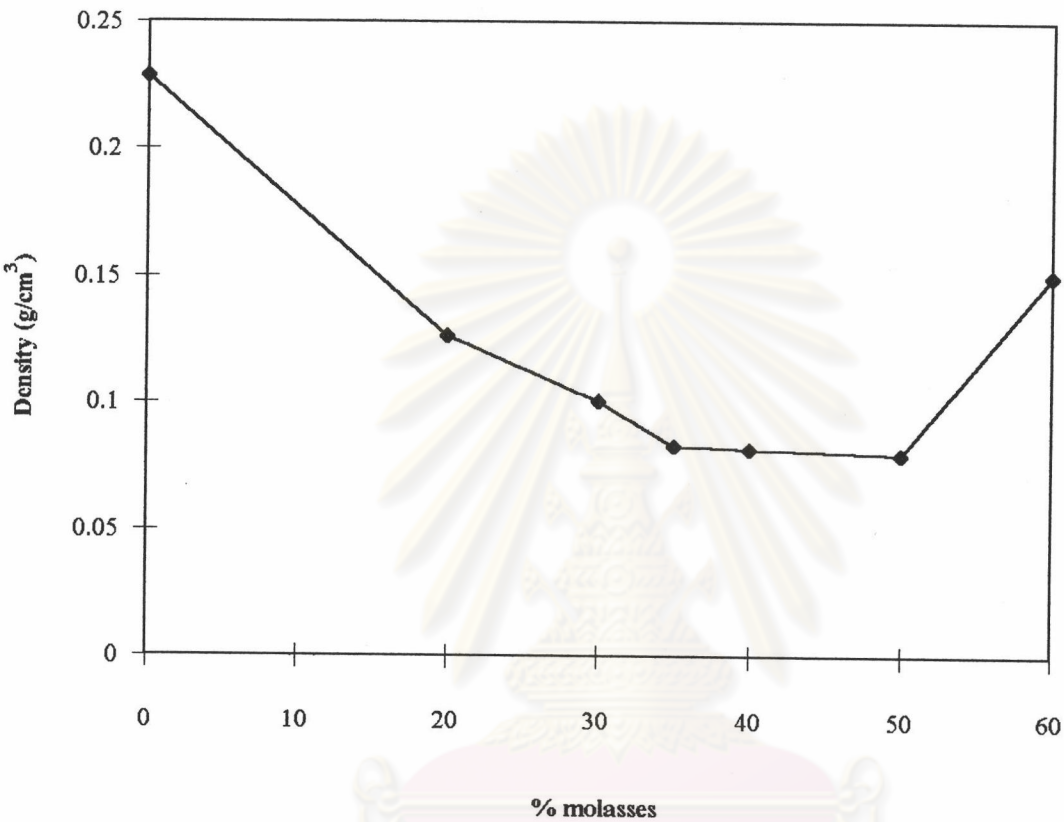


Figure 5.1 Effect of % molasses on density of polyurethane foam

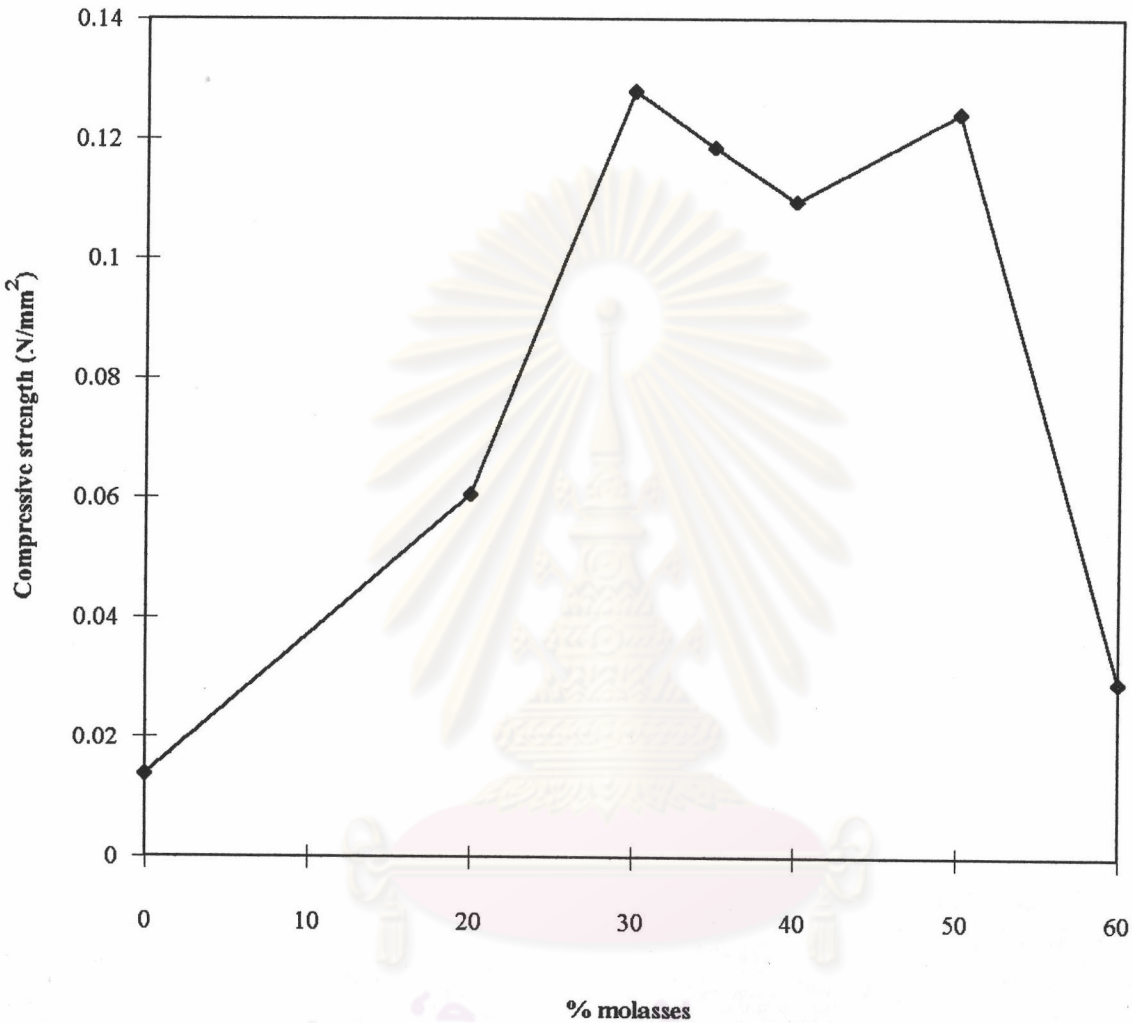


Figure 5.2 Effect of % molasses on compressive strength of polyurethane foam

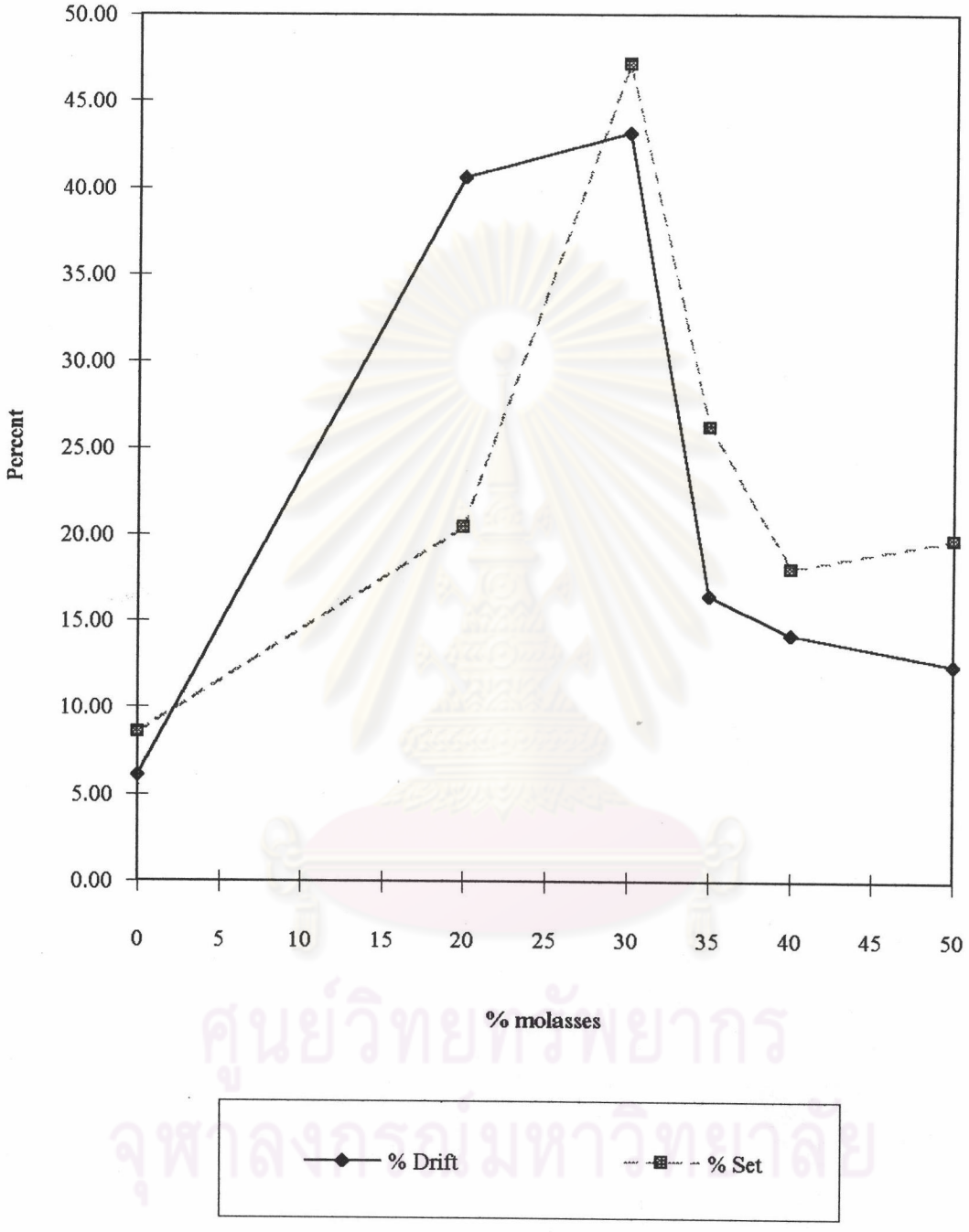


Figure 5.3 Effect of % molasses on %drift & set

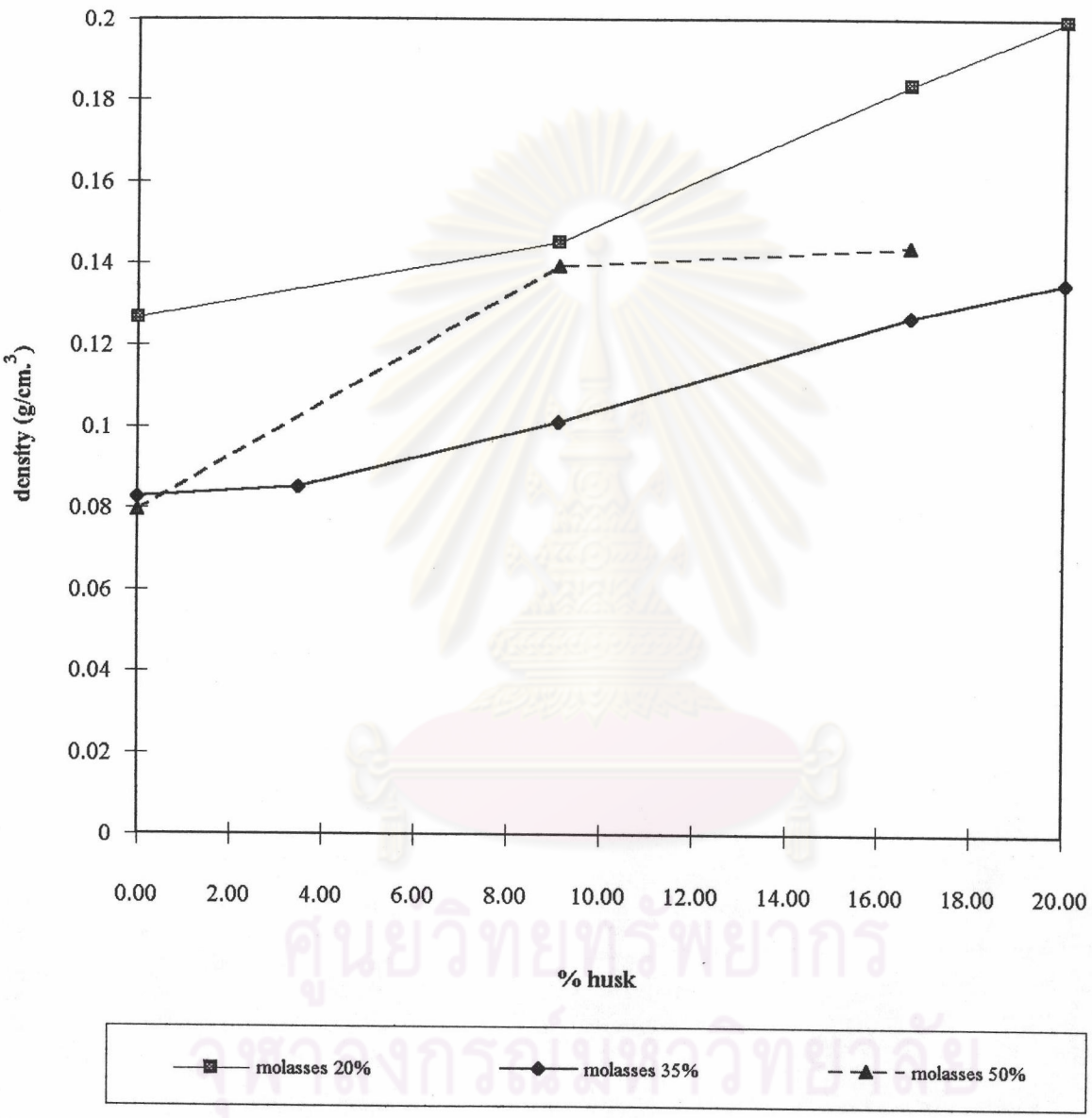


Figure 5.4 Effect of various % husk on density with a fixed % molasses of 20, 35 and 50

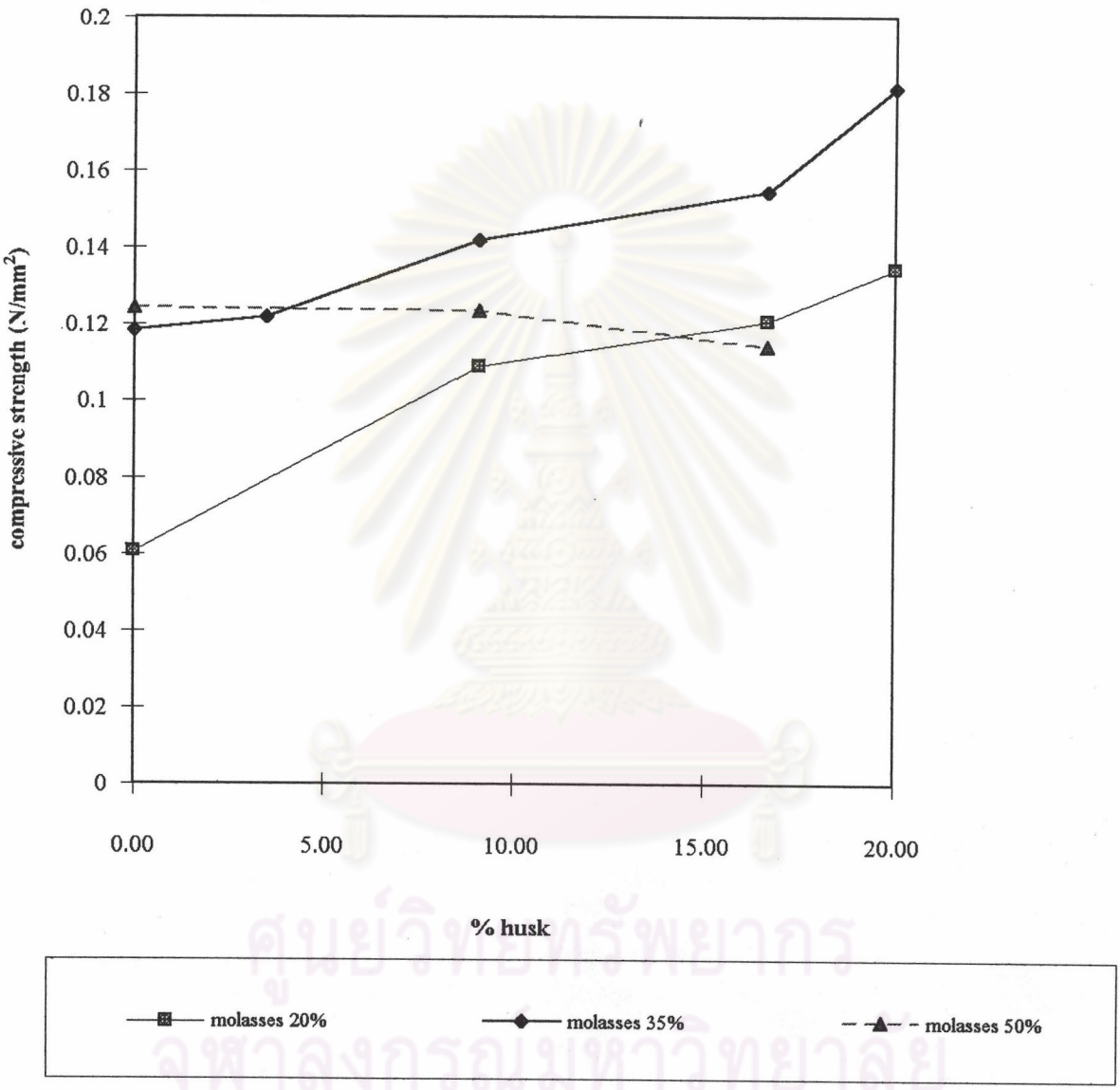


Figure 5.5 Effect of various weight % husk on compressive strength with a fixed % molasses of 20, 35 and 50

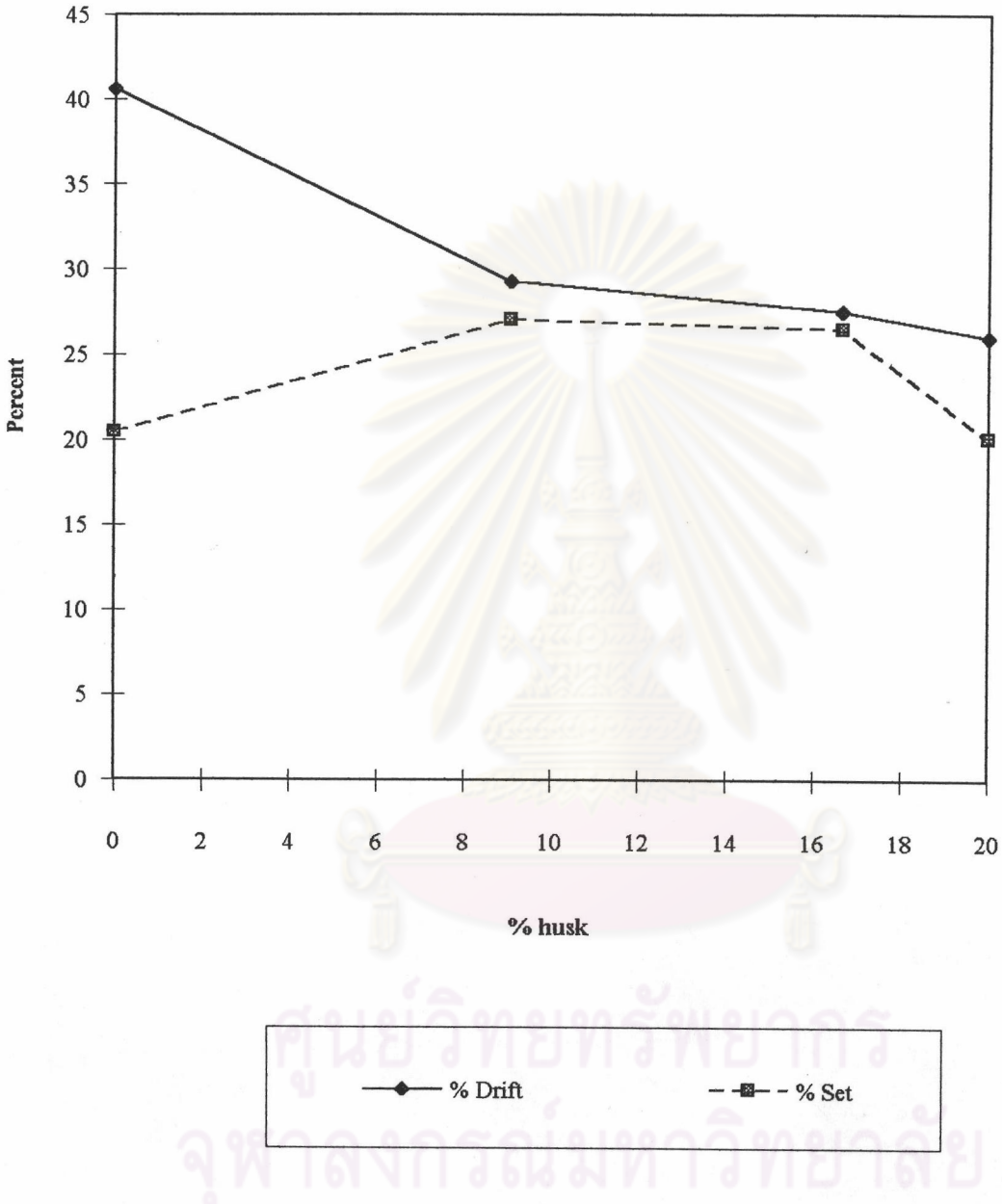


Figure 5.6 Effect of various % husk on % Drift & Set with a fixed % molasses of 20

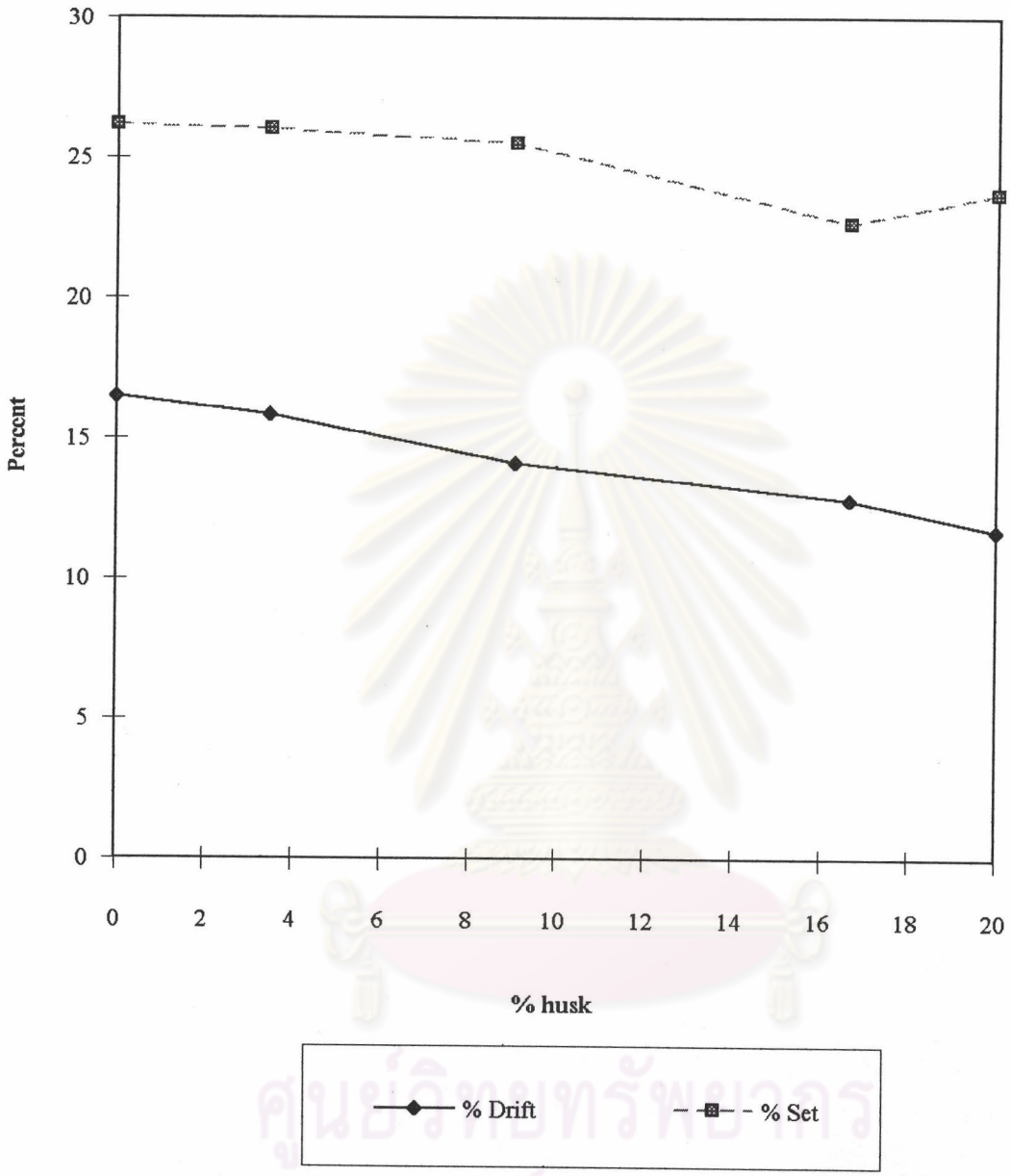


Figure 5.7 Effect of various % husk on % Drift & Set with a fixed % molasses of 35

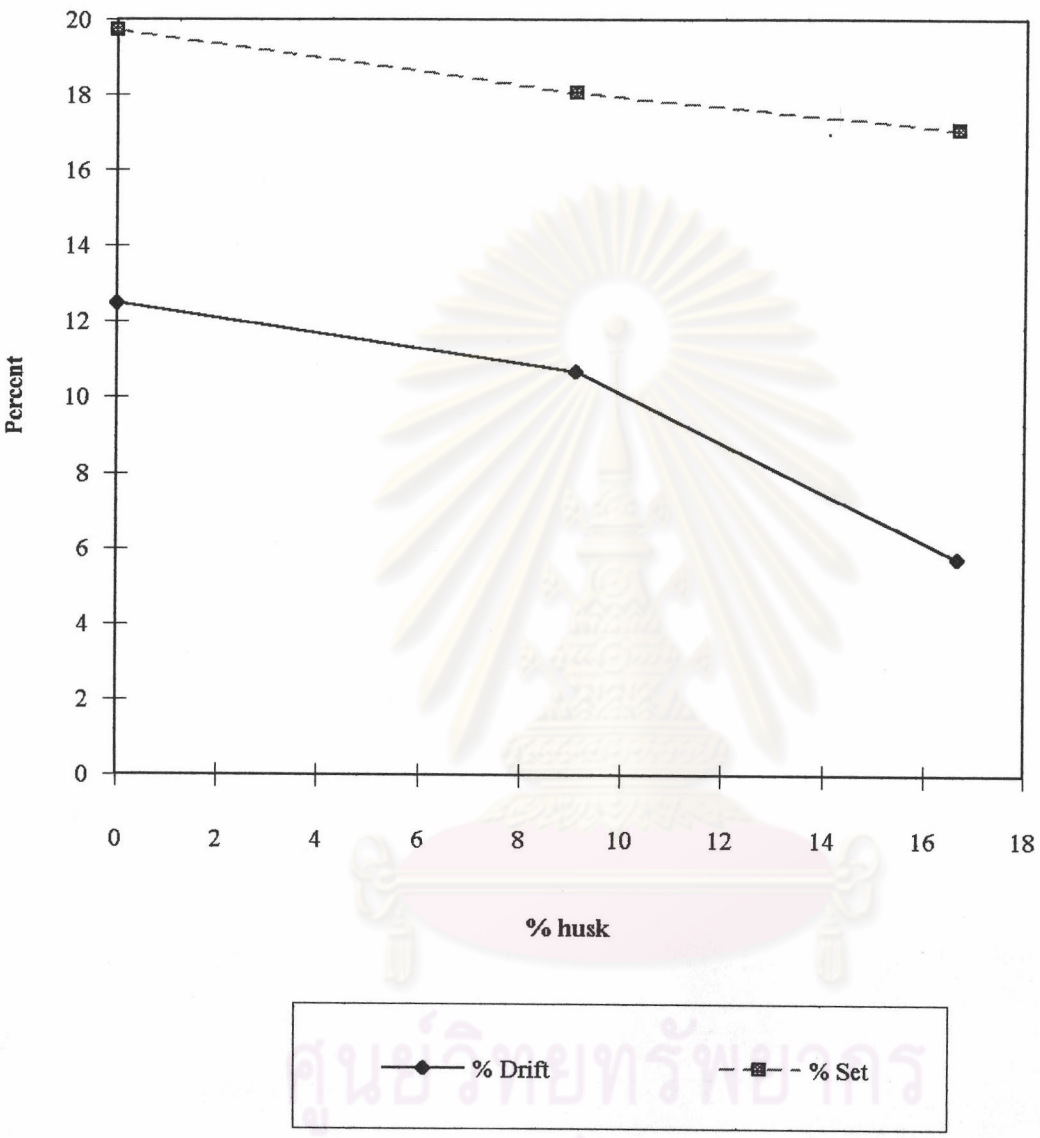


Figure 5.8 Effect of various % husk on % Drift & Set with a fixed % molasses of 50

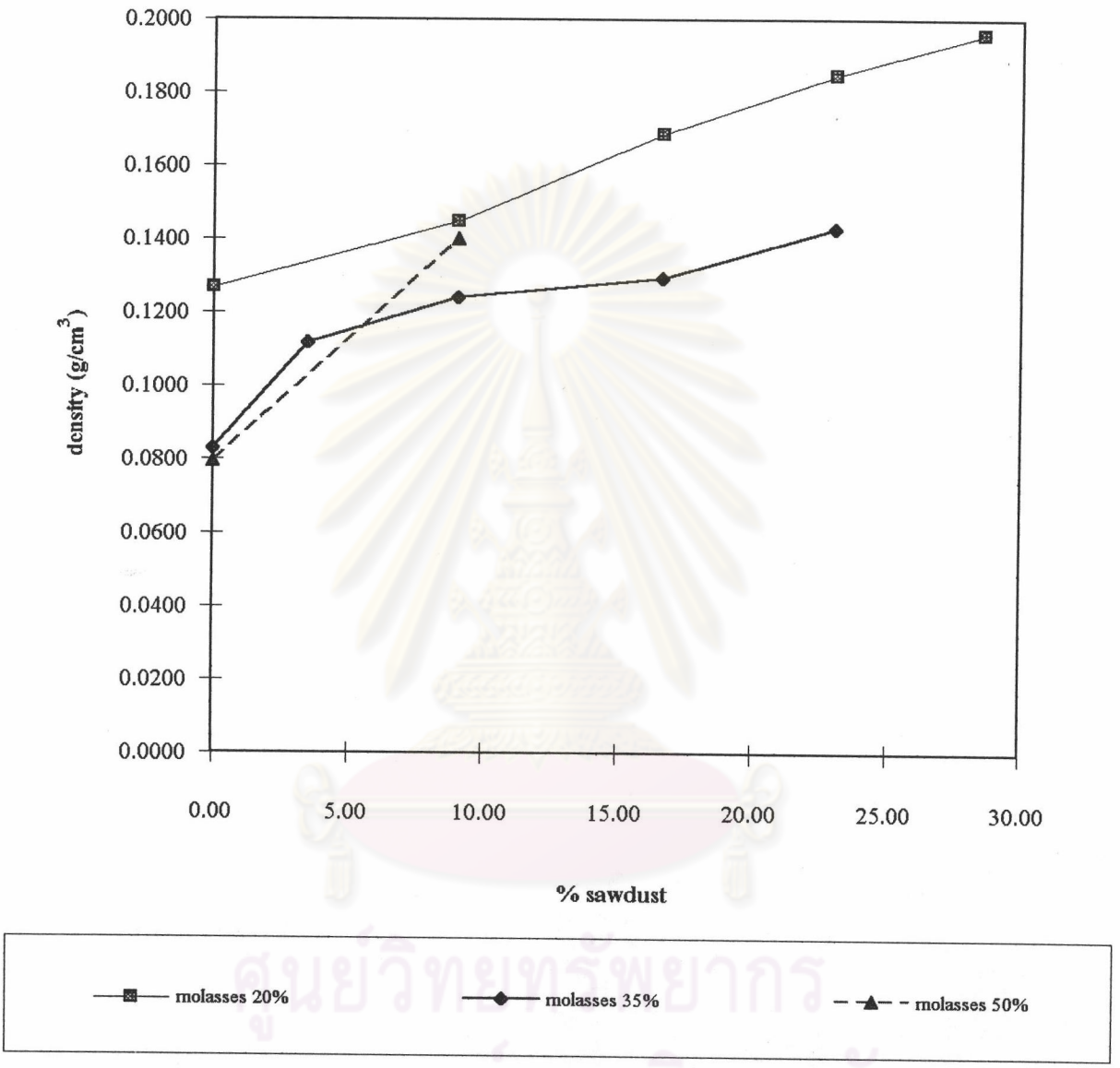


Figure 5.9 Effect of various weight % sawdust on density with a fixed %molasses of 20, 35 and 50

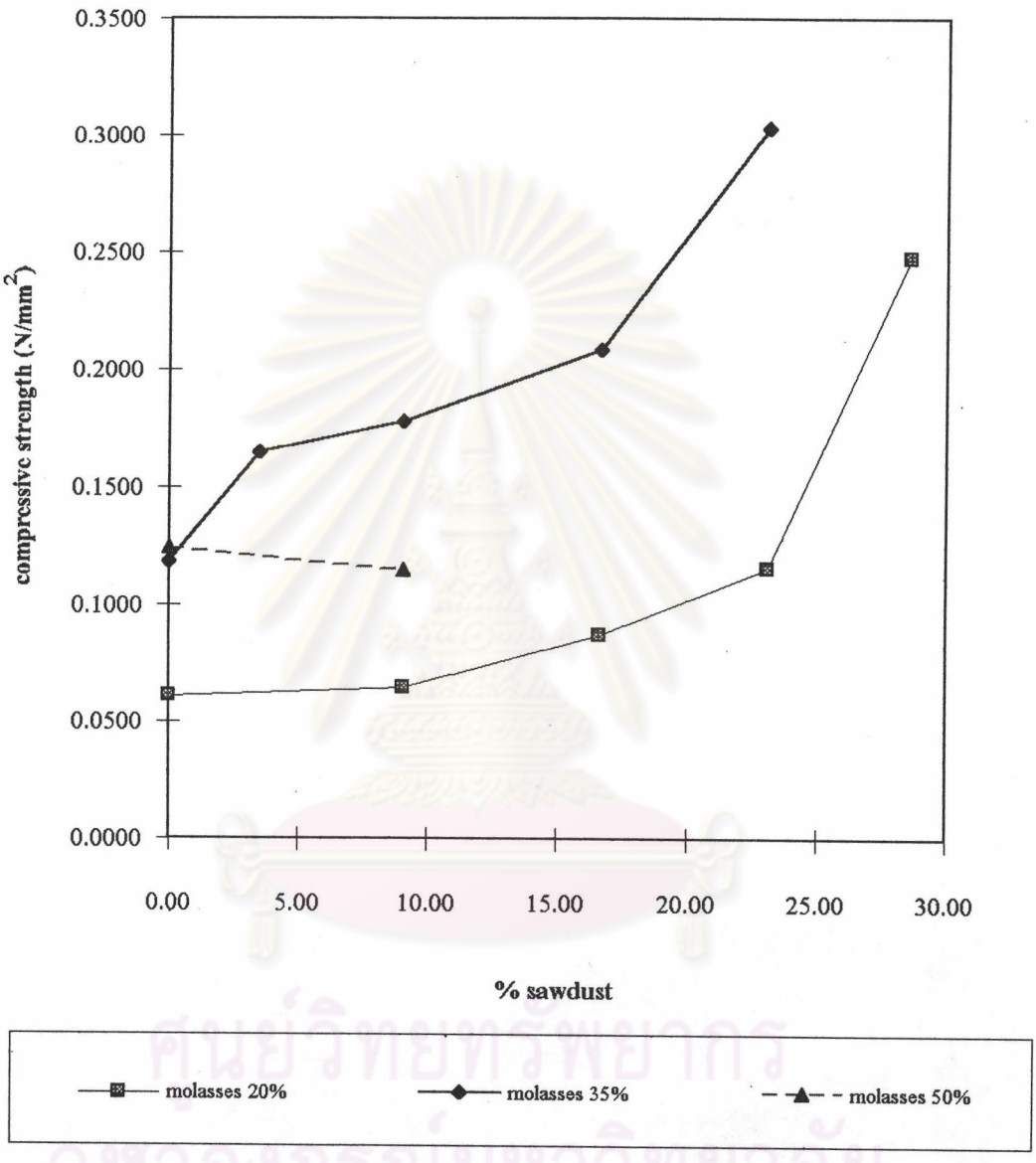


Figure 5.10 Effect of various weight % sawdust on compressive strength with a fixed % molasses of 20. 35 and 50

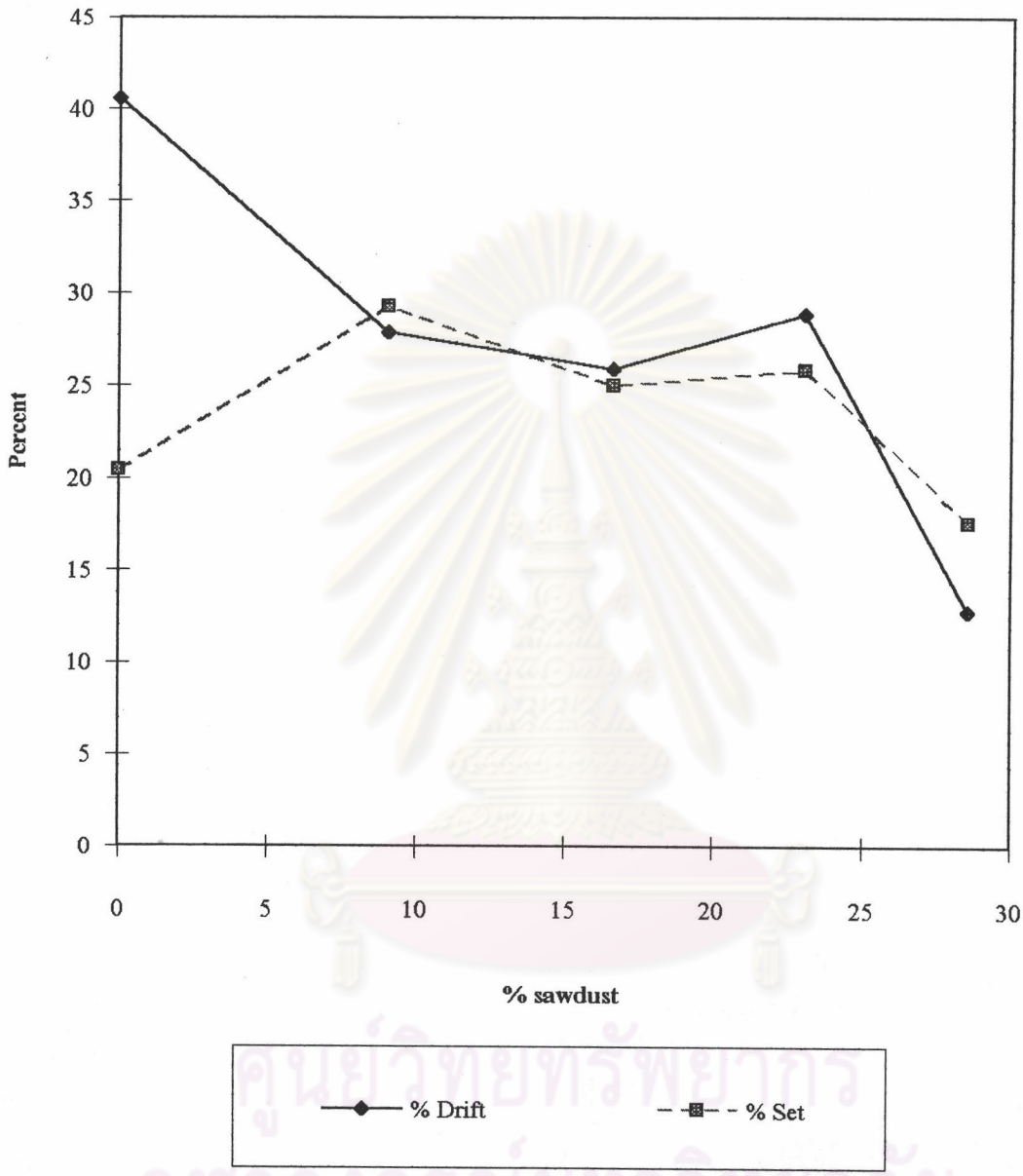


Figure 5.11 Effect of various %sawdust on %Drift & Set with a fixed %molasses of 20 and a fixed size of sawdust of 0.300-0.212 mm.

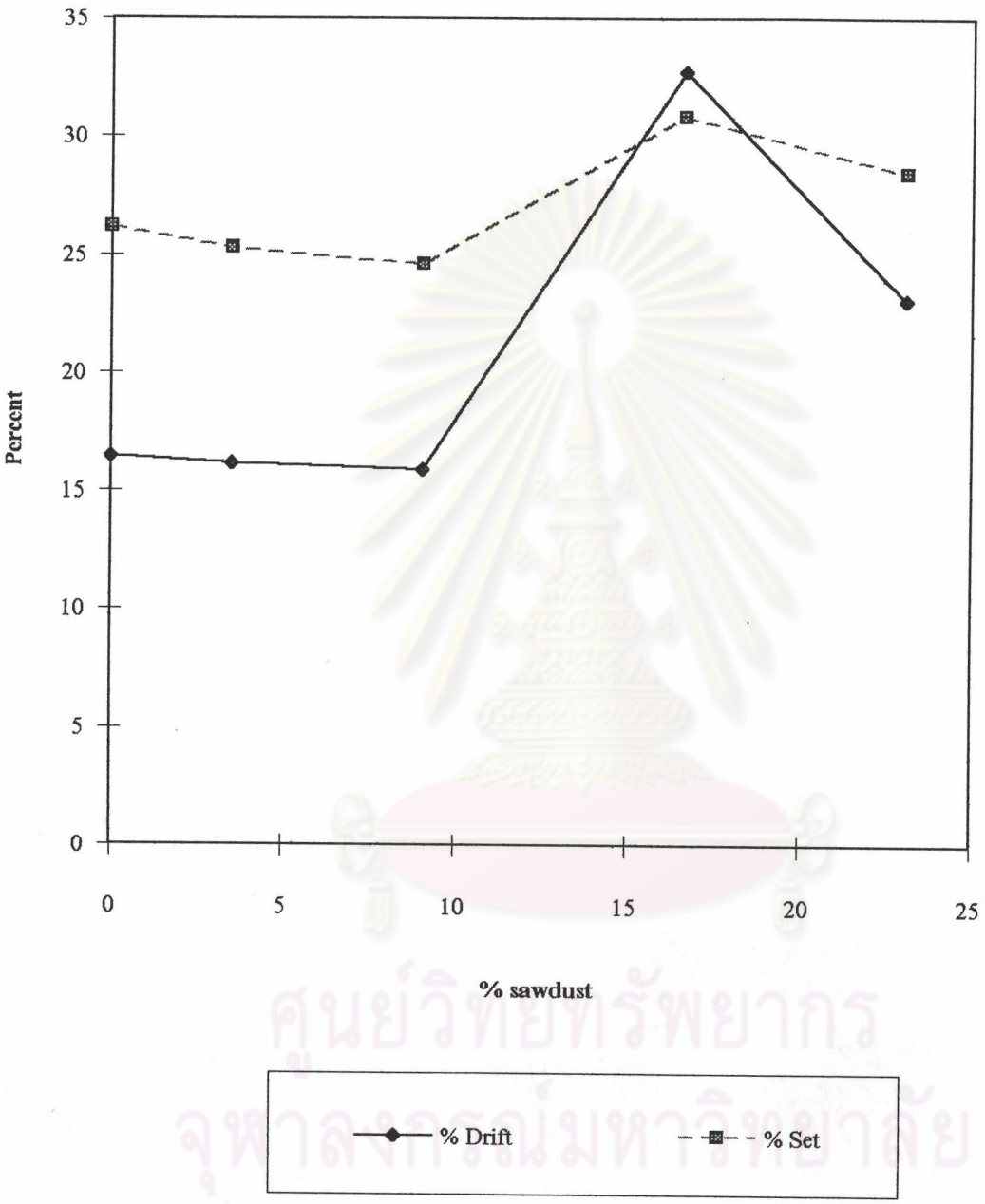


Figure 5.12 Effect of various %sawdust on %Drift & Set with a fixed %molasses of 35 and a fixed size of sawdust of 0.300-0.212 mm.

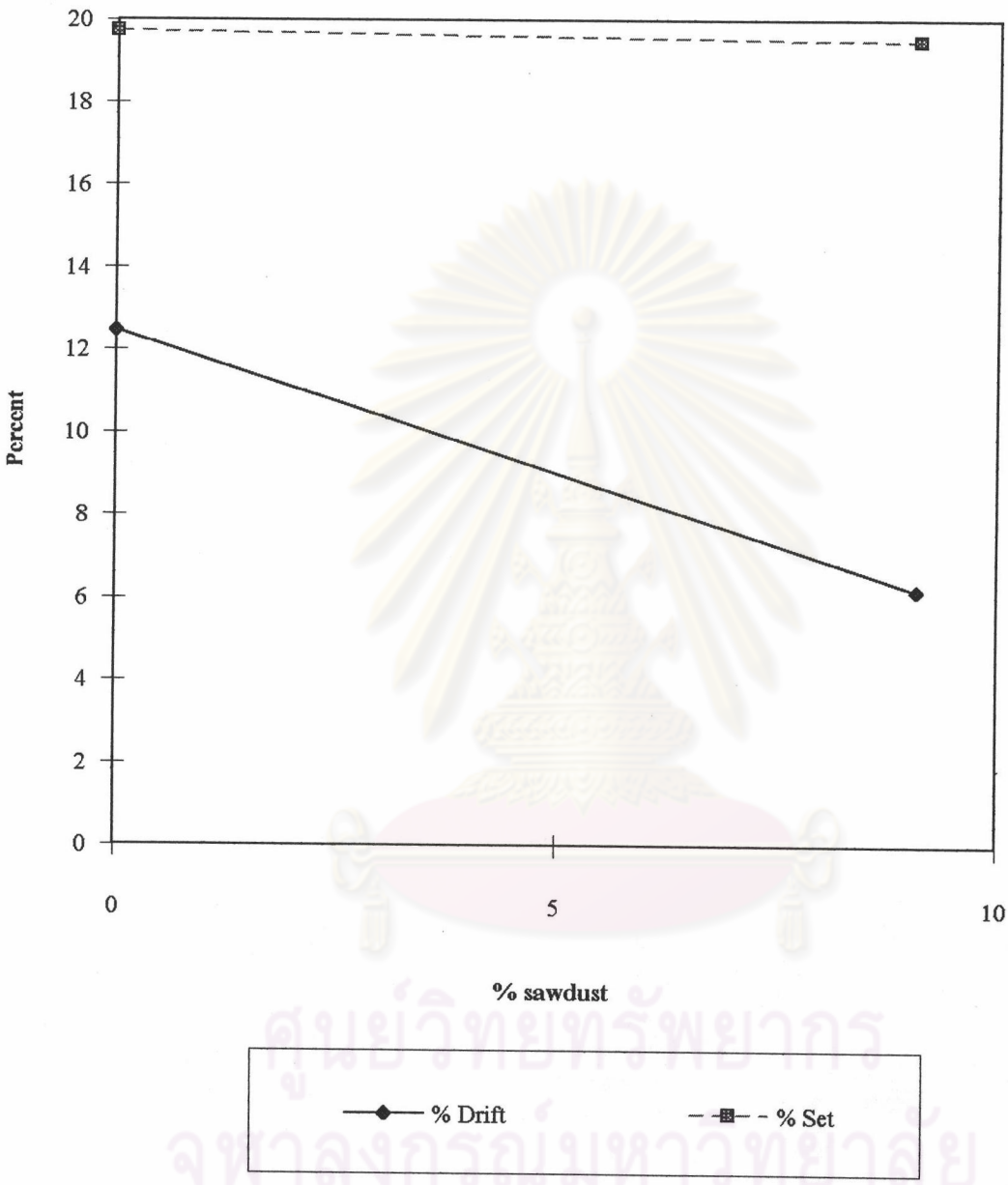


Figure 5.13 Effect of various %sawdust on %Drift & Set with a fixed %molasses of 50 and a fixed size of sawdust of 0.425-0.300 mm.

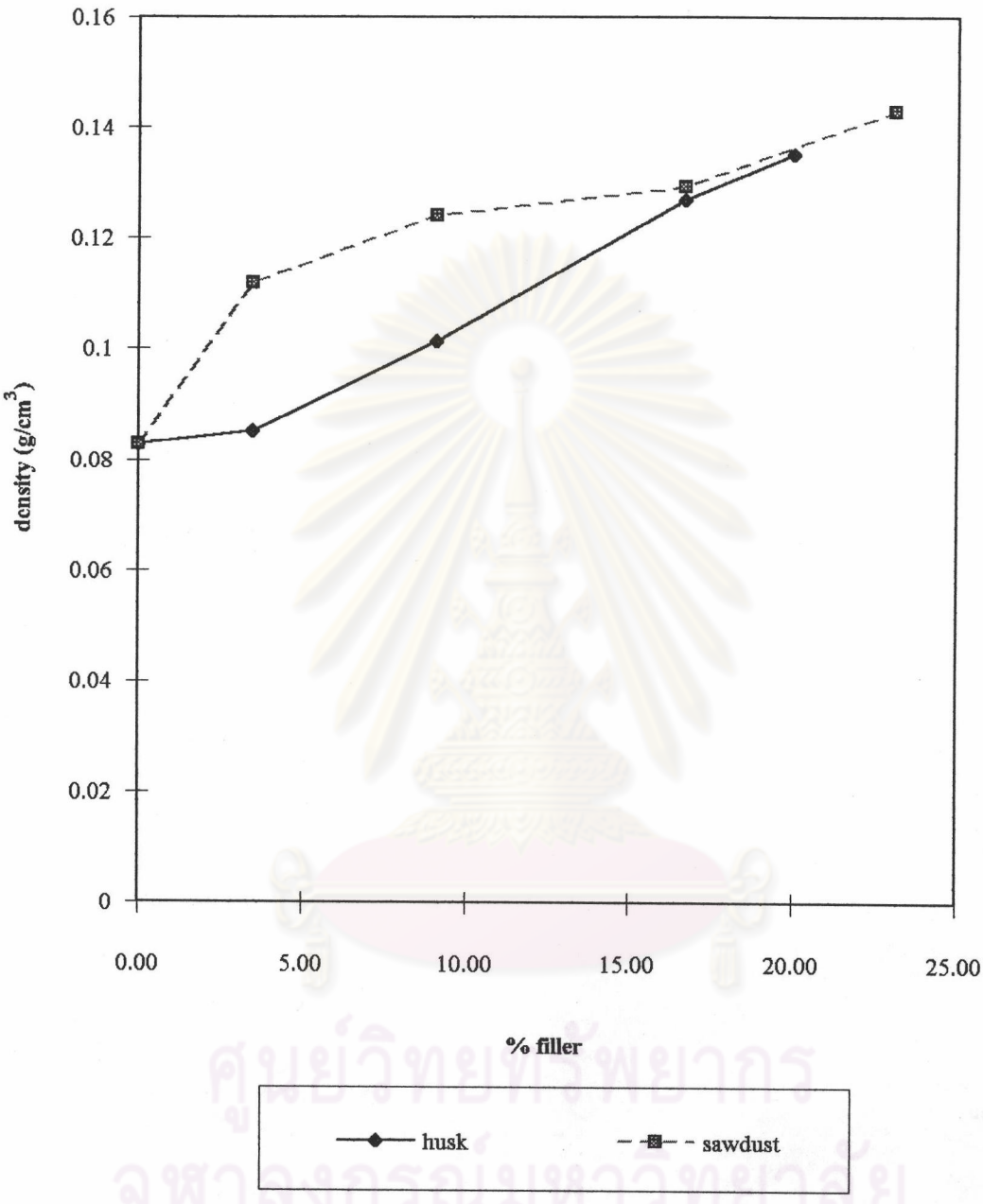


Figure 5.14 Effect of various kind of filler on density with a fixed % molasses of 35

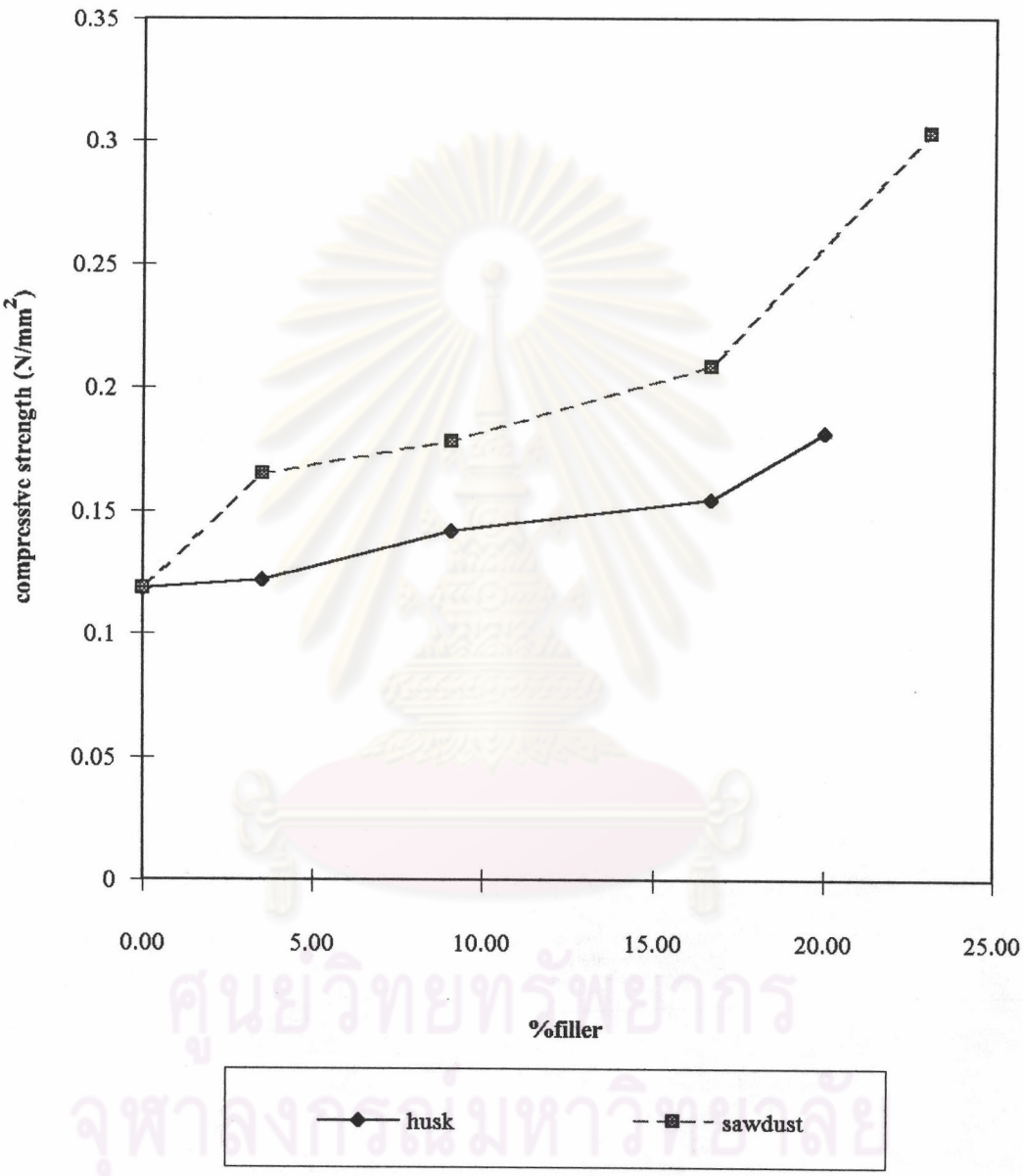


Figure 5.15 Effect of various kind of filler on compressive strength with a fixed % molasses of 35

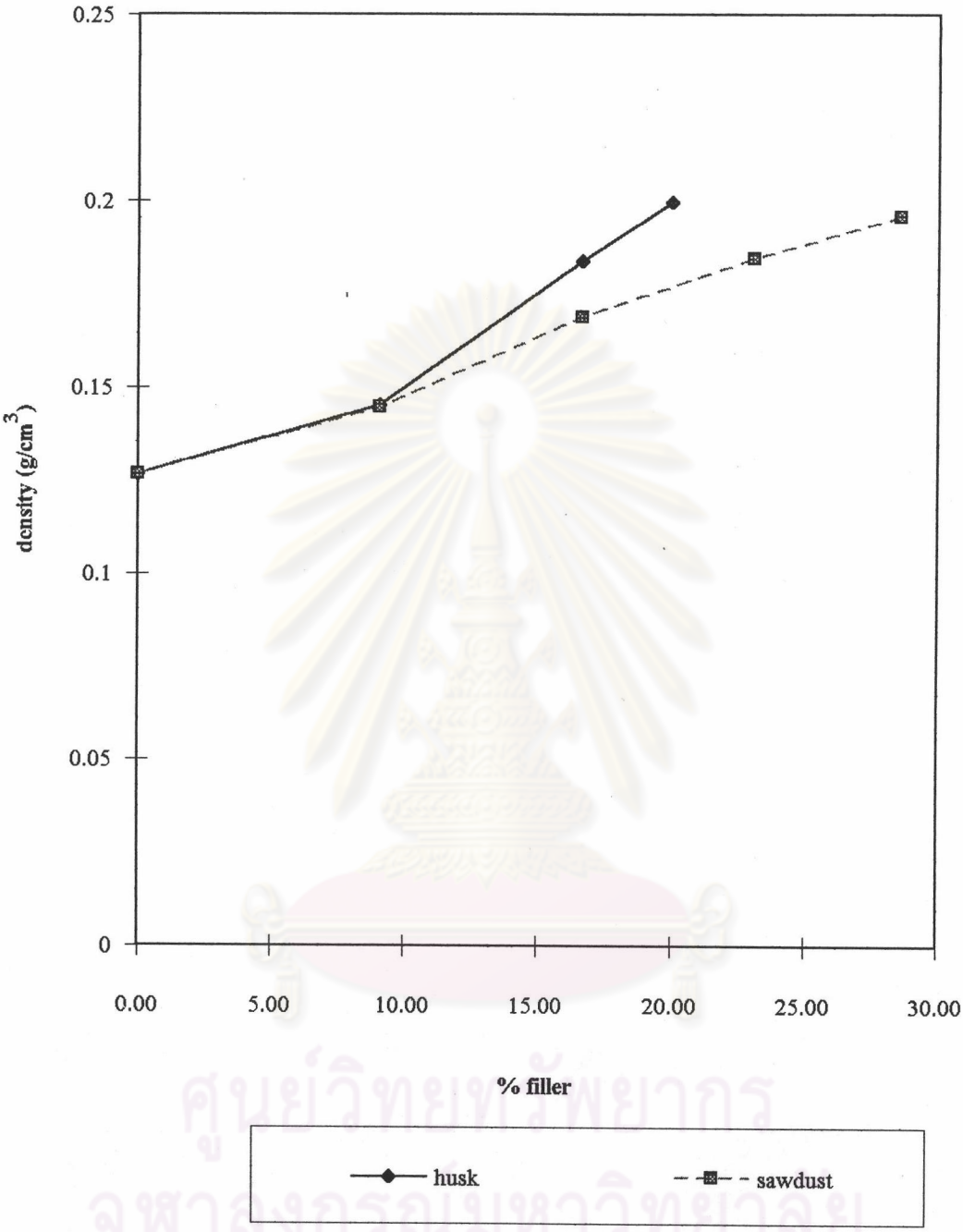


Figure 5.16 Effect of various kind of filler on density with a fixed % molasses of 20

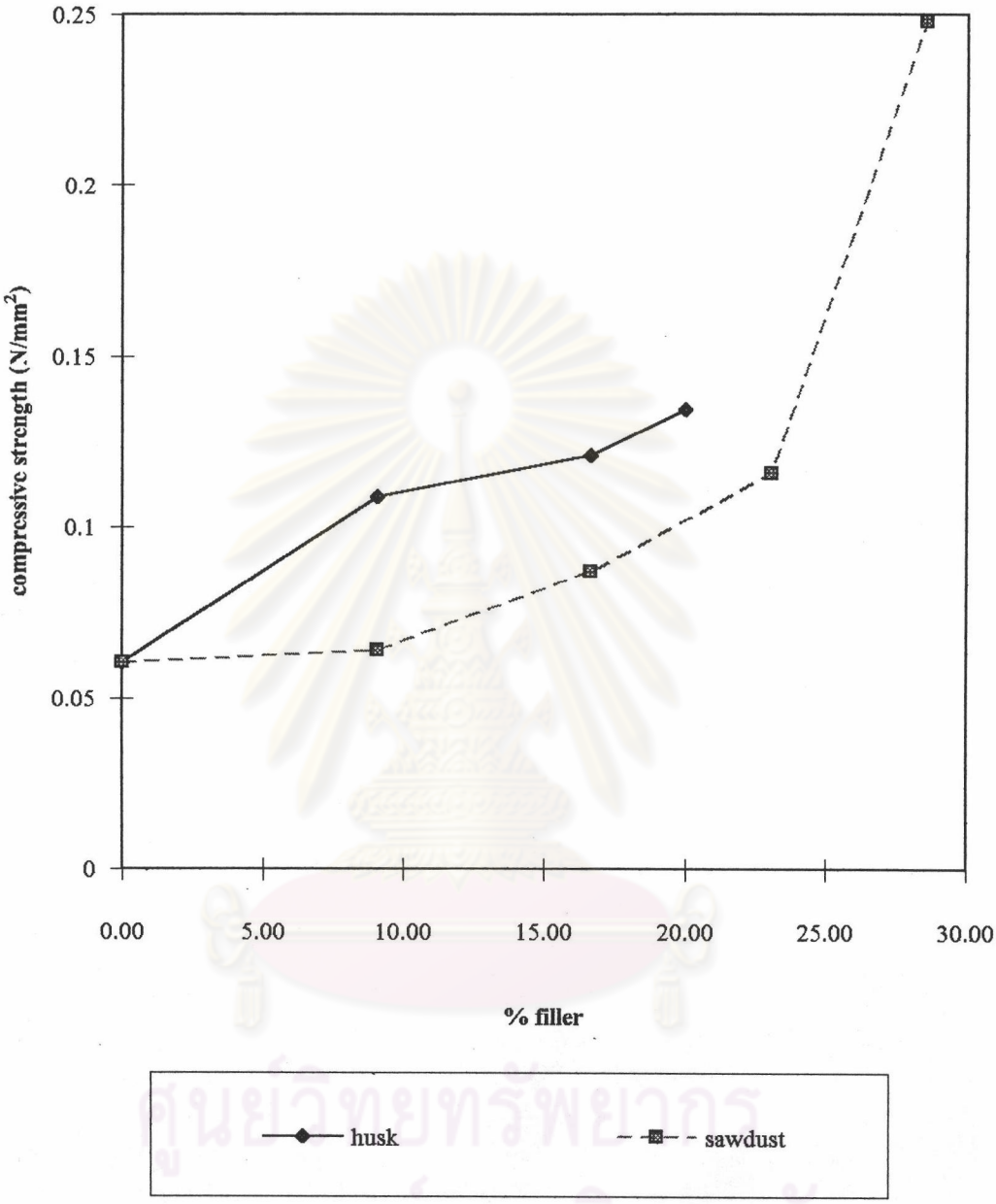


Figure 5.17 Effect of various kind of filler on compresssive strength with a fixed % molasses of 20

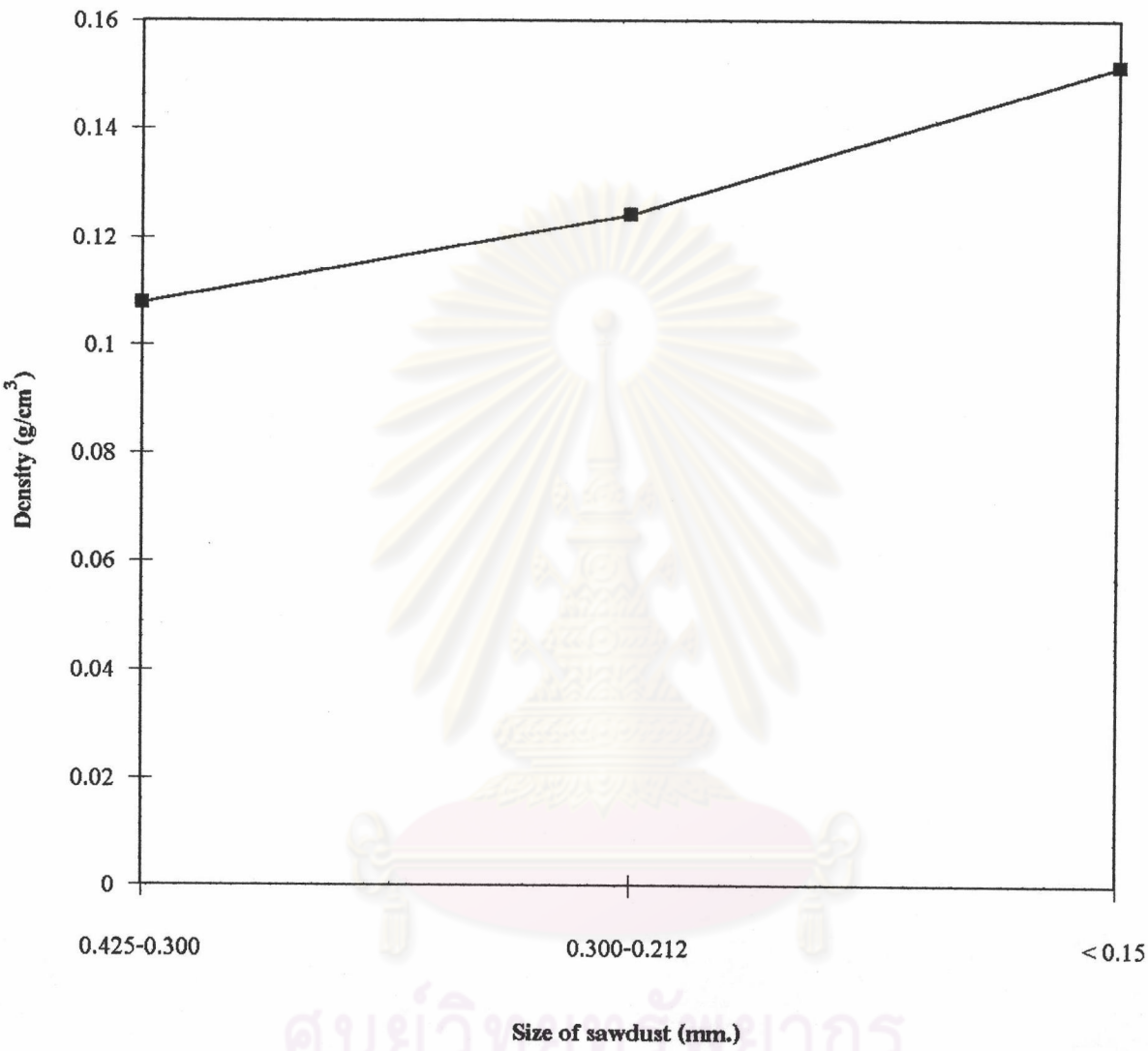


Figure 5.18 Effect of various size of sawdust on density with a fixed % sawdust of 9.09 and a fixed % molasses of 35

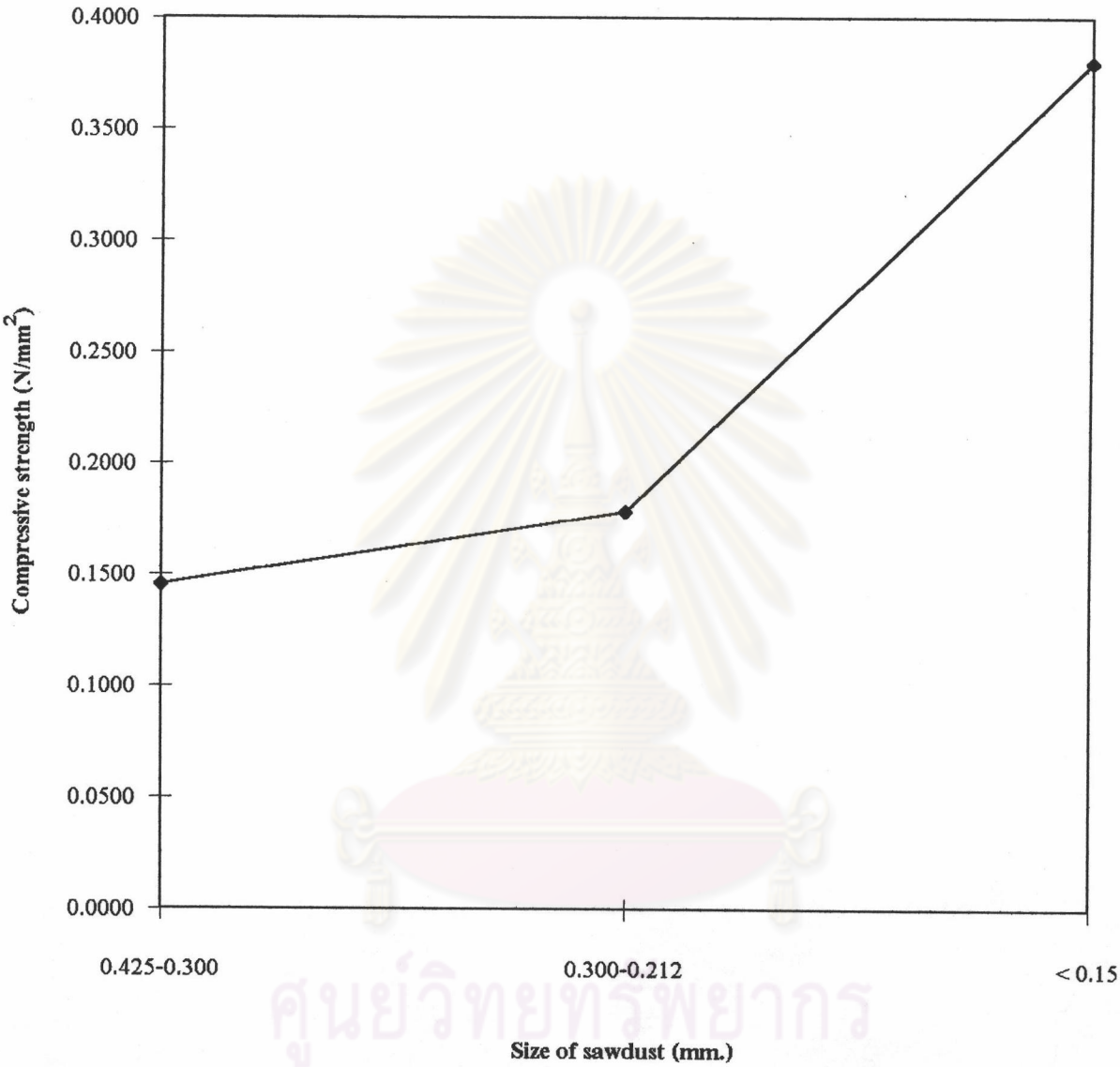


Figure 5.19 Effect of various size of sawdust on cpmpressive strength with a fixed % sawdust of 9.09 and a fixed % molasses of 35

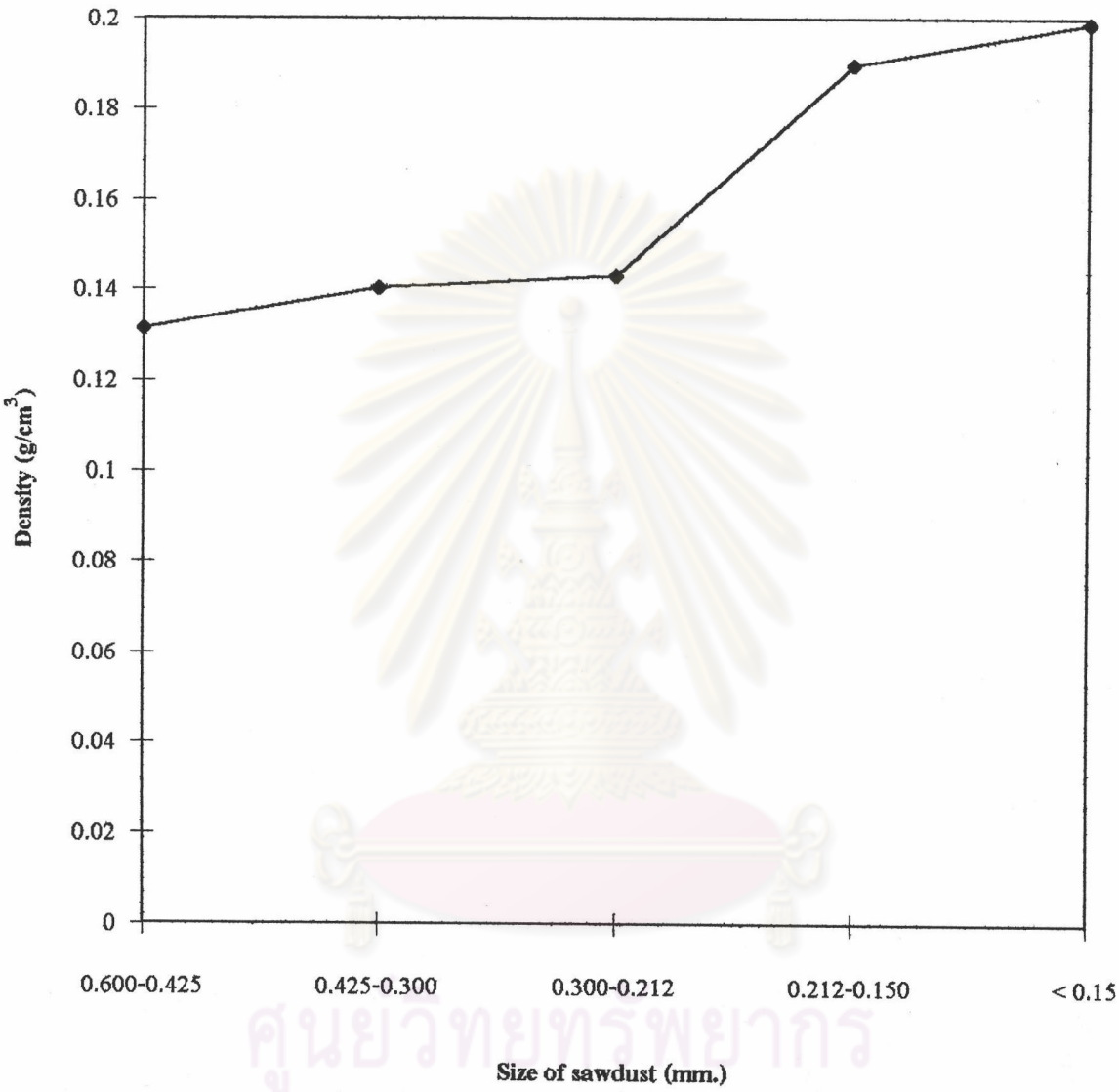


Figure 5.20 Effect of various size of sawdust on density with a fixed % sawdust of 23.08 and a fixed % molasses of 35

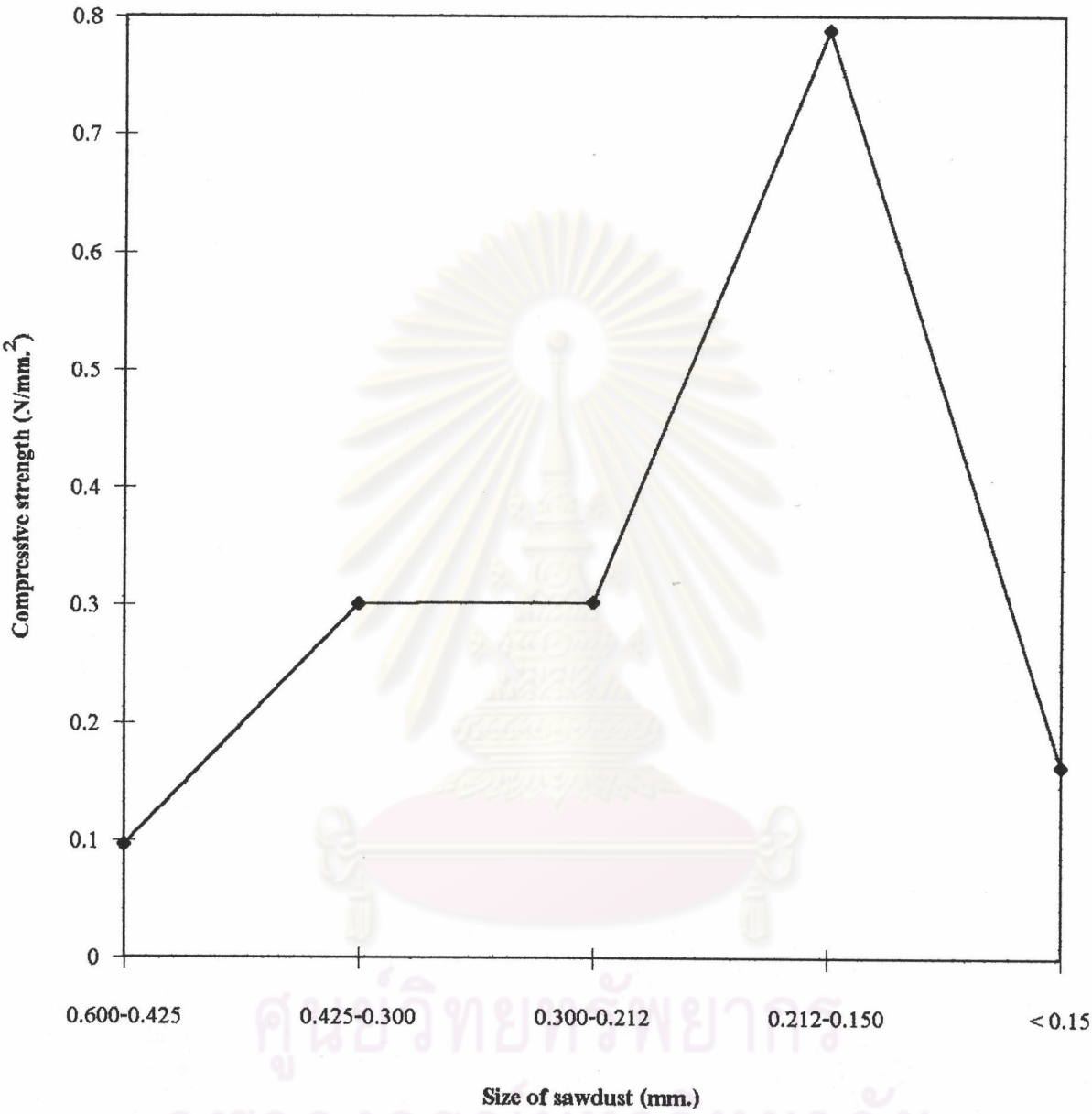


Figure 5.21 Effect ofvarious size of sawdust on compressive strength with a fixed % sawdust of 23.08 and a fixed % molasses of 35

CHAPTER 6

DISSCUSSION AND CONCLUSION

6.1 Discussion

6.1.1 Manufacturing Condition and Procedure

Prior to the experiment which gives the result in Chapter 5, preliminary experimental study was done in order to set up manufacturing procedure. The experiment used in this work study was simple and easy to use for making moldable water blown polyurethane foam. The mechanical property of polyurethane used for packaging should be in range of standard of U.S. Pat. No. 4,439,551 and 5,187,204.

The condition and procedure were described in Chapter 4. Reacting mixture of less than 200 g. was used in each batch.

During the polymerization, a typical temperture rise in the reacton mixture is shown in Figure 6.1.

Table 6.1 Relation of temperature and time

Time (min.)	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Temp. (°C)	29	30	31.5	33	34	35	36	37	38	39	39.5	40	40.5	41	41.5	42

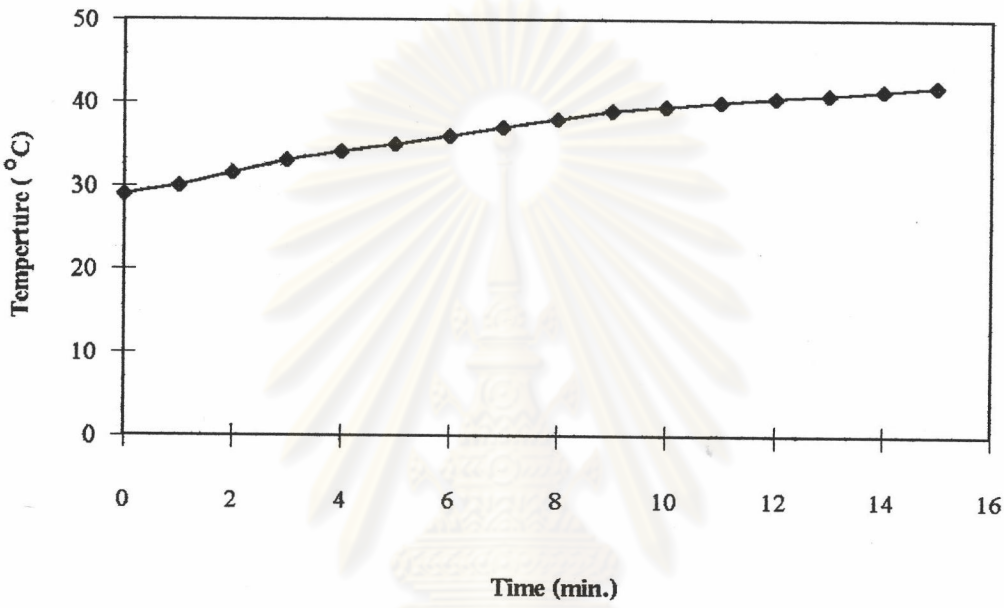


Figure 6.1 Relation of temperture and time

6.1.2 Suitable Composition of Filled-Polyurethane

(a) Raw materials.

The raw mateials used in this work are selected based on the following criteria:

- locally available
- low cost
- biodegradable

In this study polyether polyol, polymeric MDI and catalyst were supplied by TPU (Thai Polyurethane Industry Co.,Ltd.). Molasses, husk and sawdust are found easily at low cost.

(b) Suitable composition

First, the effect of molasses on mechanical properties is determined, it was found that saccharide in molasses acts as hard segments in polyurethane molecular netwoks. Water in molasses is able to react with polymeric MDI and give carbondioxide that acts as blowing agent. High content of molasses will give a high compressive strength, low drift and set and low density foam which are good properties for packaging, but when % molasses increase to 60 the product became brittle.

From Table 6.2 and Figure 6.2, value of compressive strength devided by density of the foam and their costs are presented. According to U.S. Pat. No. 4,439,551 and 5,187,204, the criteria for good energy absorbing foam is a value of compressive strength less than 28 psi. (0.193 N/mm^2) at 50 percent deflection.
At % molasses of 50 the best properties are obtained but at higher cost. Then,
% molasses of 20 and 35 were chosen for use as packaging of lower weight object because of their lower cost.

After the composition of unfilled polyurethane is obtained, the type and percentage of filler is dertermined. Filler was filled in foam to improve the mechanical properties and reduce cost of products. According to Table 5.4 and 5.7 and Figure 5.4, 5.5, 5.9 and 5.10, at % molasses of 50, husk and sawdust had effect on increasing

density but decreasing compressive strength at 10 percent deformation while compressive strength at 50 percent deflection rises up to over 0.193 N/mm^2. So, at % molasses of 50, filled-polyurethane foam is not suitable to be used as packaging material.

At % molasses of 20 and 35, husk and sawdust not only increase compressive strength and decrease drift and set, but also reduce cost of product. Based on Table 5.2, 5.3 and 5.5 and Figure 6.3, 6.4, 6.6, and 6.7, at fixed % molasses of 20, a 9.09% of husk and sawdust was chosen because they had compressive strength at 50% deflection not over 0.193 N/mm^2, and at fixed % molasses of 35, a 3.51% of husk was chosen for the same reason, this product give a better mechanical properties but higher cost than product consisted of molasses 20 %.

Table 6.2 Relation between machanical properties and estimate cost by variours % molasses

Molasses (%)	Comp./Den.	compressive strength at 50% deflection (N/mm^2)	cost (Baht / Kg)
0	0.0608	0.0269	52.78
20	0.4787	0.1338	51.64
30	1.2726	0.1914	52.44
35	1.4306	0.1676	52.78
40	1.3431	0.1719	53.11
50	1.5635	0.1591	53.60

comp = compressive strength

den. = density

Table 6.3 Relation between machanical properties and estimate cost by variours weight percentage of husk of a fixed % molasses of 20

% husk	comp./den.	compressive strength at 50% deflection (N/mm^2)	cost (Baht / Kg)
0.00	0.4787	0.1338	51.64
9.09	0.7507	0.1831	47.01
16.66	0.6583	0.2695	43.15
20.00	0.6738	0.3670	41.45

comp = compressive strength

den. = density

Table 6.4 Relation between machanical properties and estimate cost by variours weight percentage of husk of a fixed % molasses of 35

% husk	comp./den.	compressive strength at 50% deflection (N/mm^2)	cost (Baht / Kg)
0.00	1.4306	0.1676	52.78
3.51	1.4319	0.1876	50.95
9.09	1.4008	0.2843	48.05
16.67	1.2183	0.4192	44.10
20.00	1.3439	0.5086	42.37

comp = compressive strength

den. = density

Table 6.5 Relation between machanical properties and estimate cost by variours weight percentage of husk of a fixed % molasses of 50

% husk	comp./den.	compressive strength at 50% deflection (N/mm^2)	cost (Baht / Kg)
0.00	1.5635	0.1591	53.60
9.09	0.8866	0.6376	48.79
16.66	0.7938	0.6134	44.79

comp = compressive strength

den. = density

Table 6.6 Relation between machanical properties and estimate cost by variours weight percentage of sawdust of a fixed % molasses of 20

% sawdust	Comp/den	compressive strength at 50% deflection (N/mm^2)	cost (Bath / Kg.)
0.00	0.4787	0.1338	51.64
9.09	0.4441	0.1755	47.07
16.66	0.5172	0.1996	43.26
23.08	0.6270	0.2573	40.04
28.57	1.2648	0.521	37.28

comp = compressive strength

den. = density

Table 6.7 Relation between machanical properties and estimate cost by variours weight percentage of sawdust of a fixed % molasses of 35

%sawdust	Comp/den	compressive strength at 50% deflection (N/mm^2)	cost (Bath / Kg.)
0.00	1.4306	0.1676	52.78
3.51	1.4767	0.3045	50.97
9.09	1.4343	0.3475	48.11
16.67	1.6141	0.7081	44.22
23.08	2.1189	0.9850	40.92

comp = compressive strength

den. =density

Table 6.8 Relation between machanical properties and estimate cost by variours weight percentage of sawdust of a fixed % molasses of 50

%sawdust	Comp/den	compressive strength at 50% deflection (N/mm^2)	cost (Bath / Kg.)
0.00	1.5635	0.1591	53.60
9.09	0.8200	0.7332	48.86

comp = compressive strength

den. =density

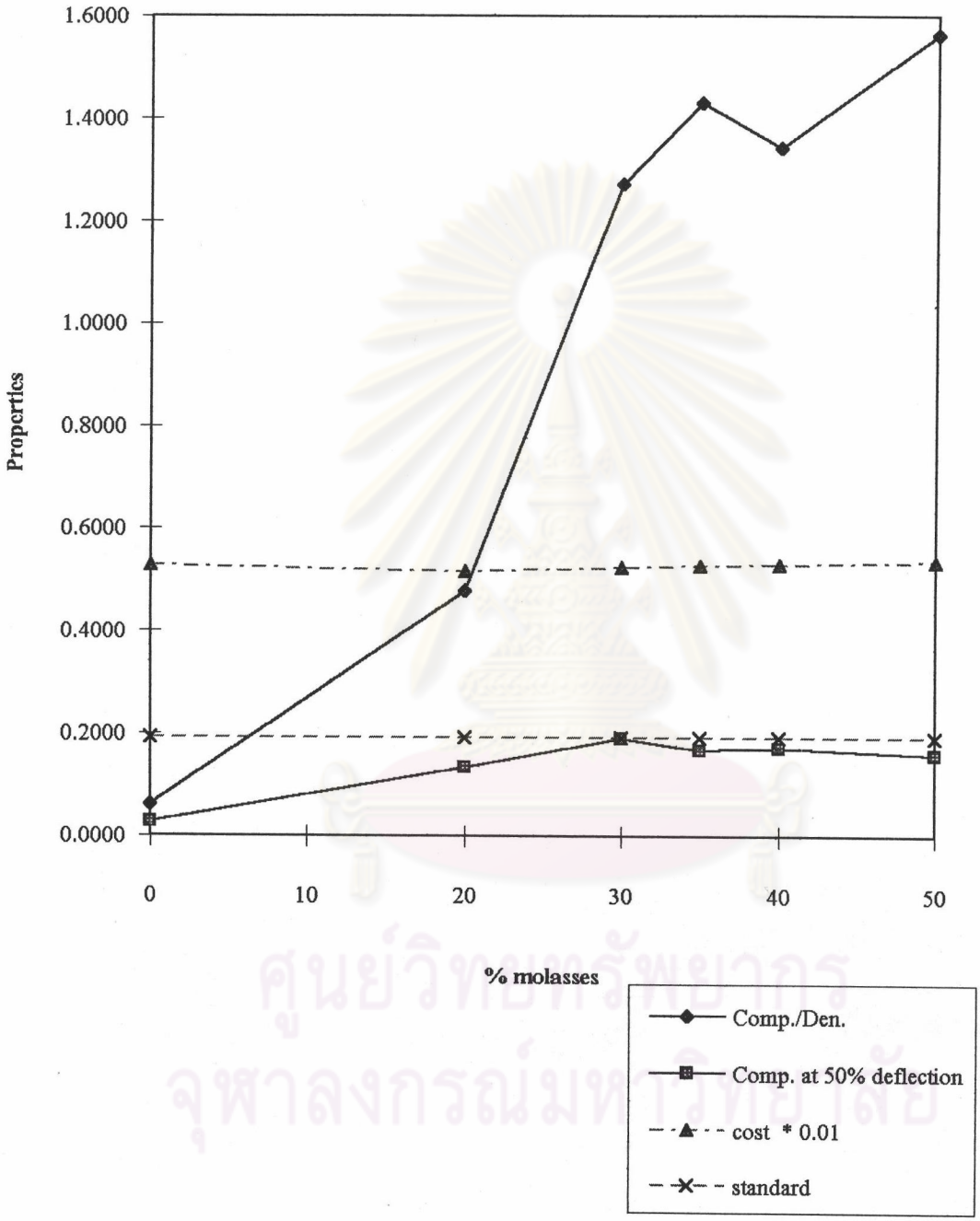


Figure 6.2 Relation between mechanical properties and estimate cost by various % molasses

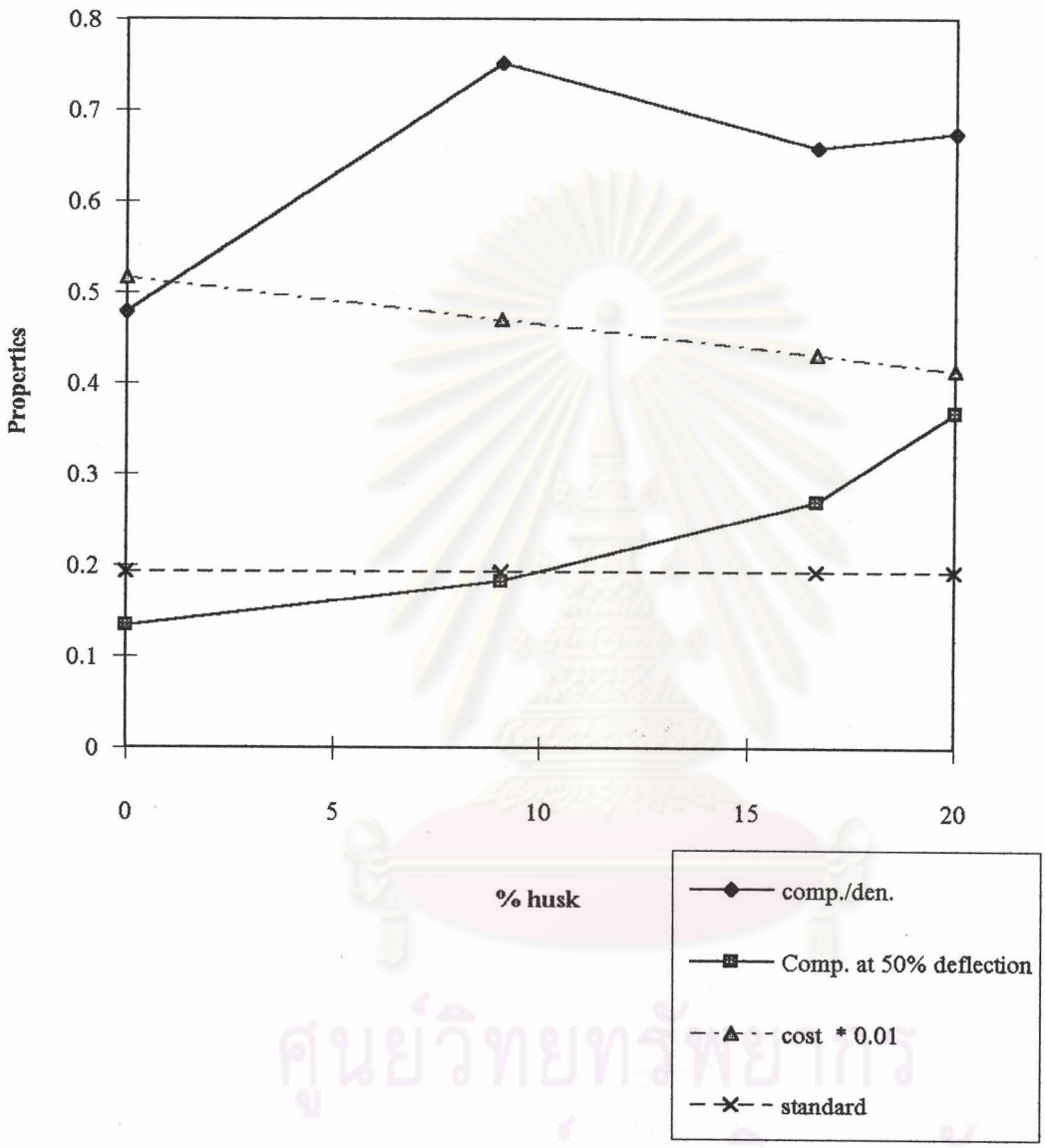


Figure 6.3 Relation between mechanical properties and estimate cost by various weight percentage of husk at a fixed % molasses of 20

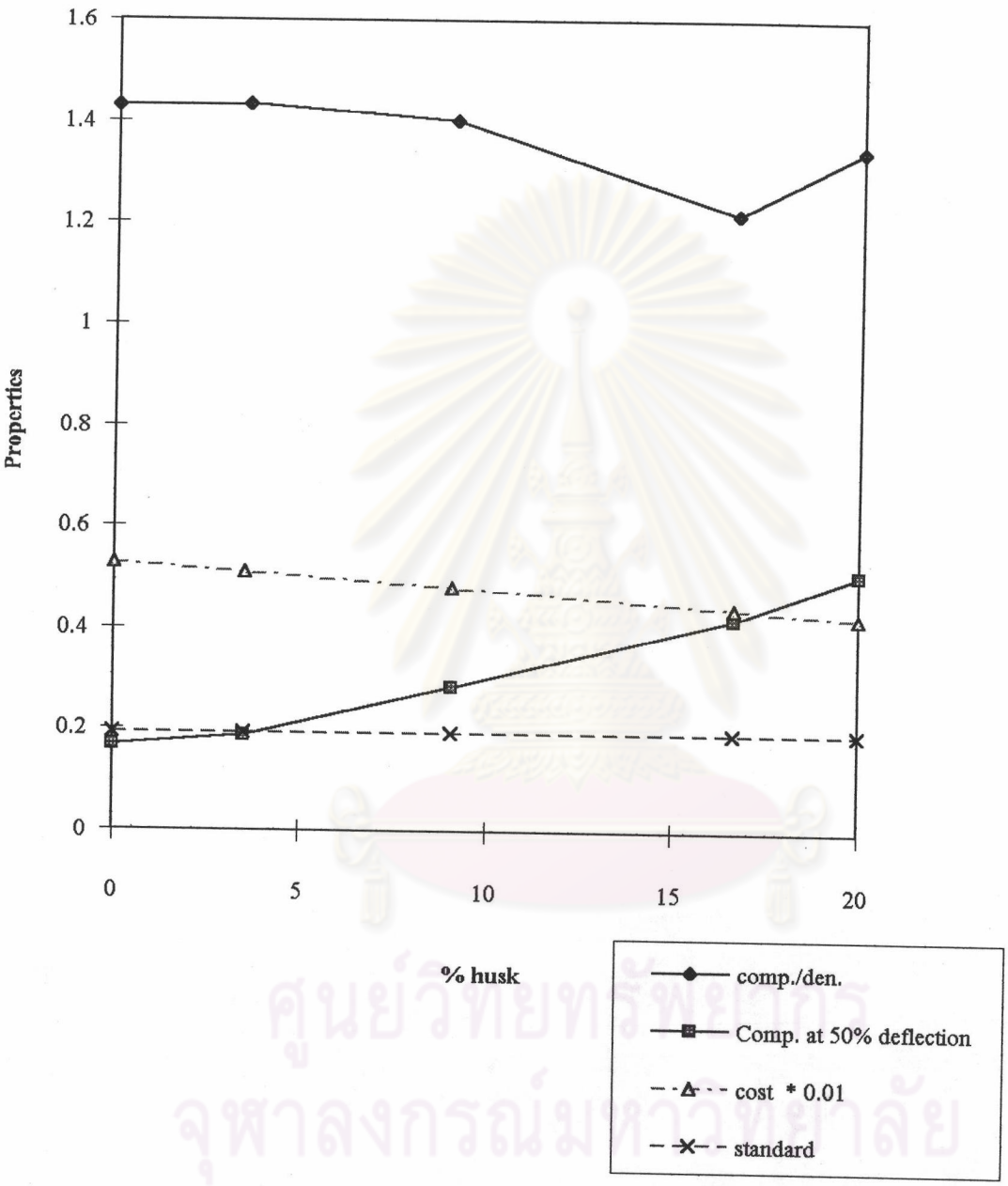


Figure 6.4 Relation between mechanical properties and estimate cost by various weight percentage of husk at a fixed % molasses of 35

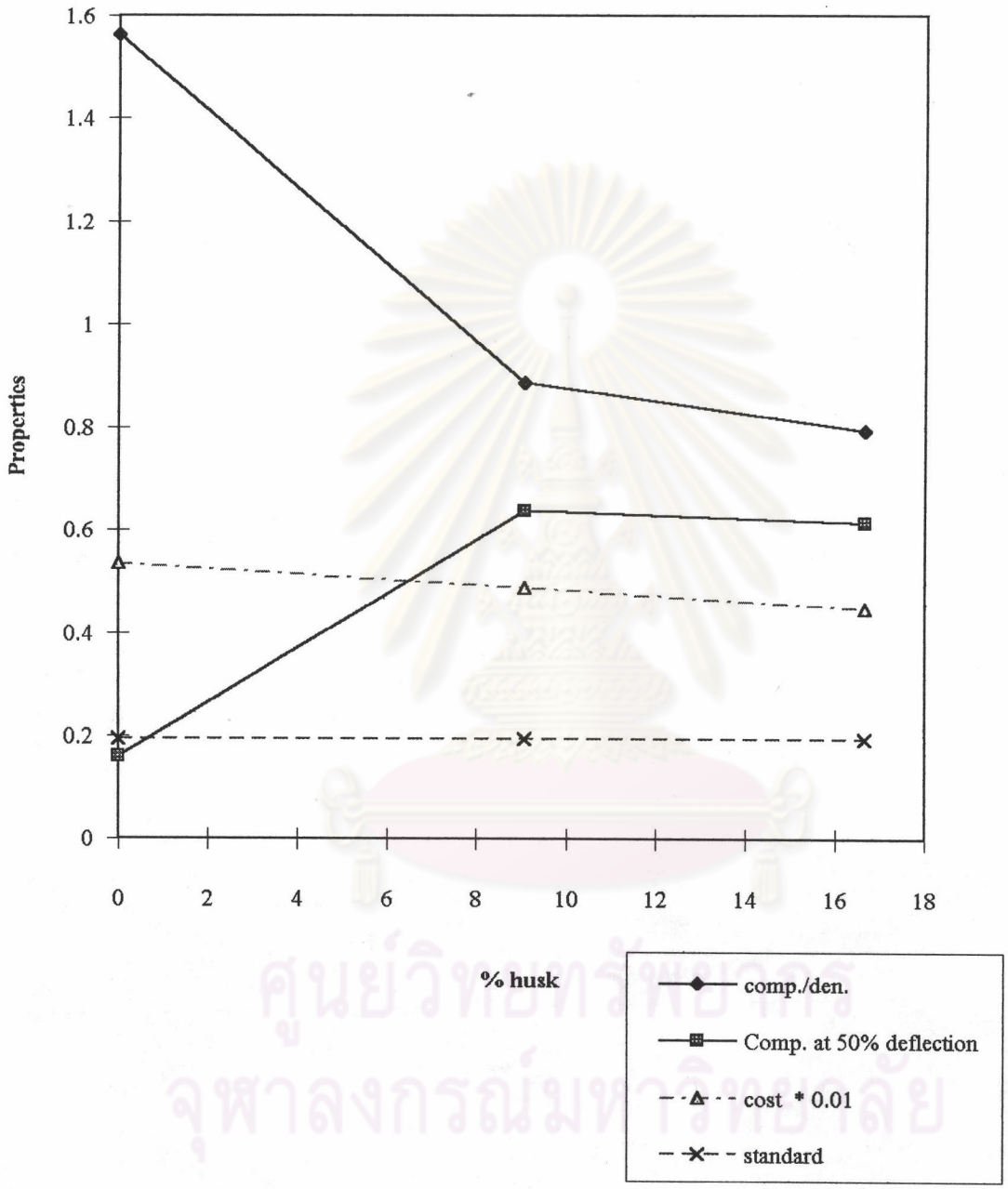


Figure 6.5 Relation between mechanical properties and estimate cost by various weight percentage of husk at a fixed % molasses of 50

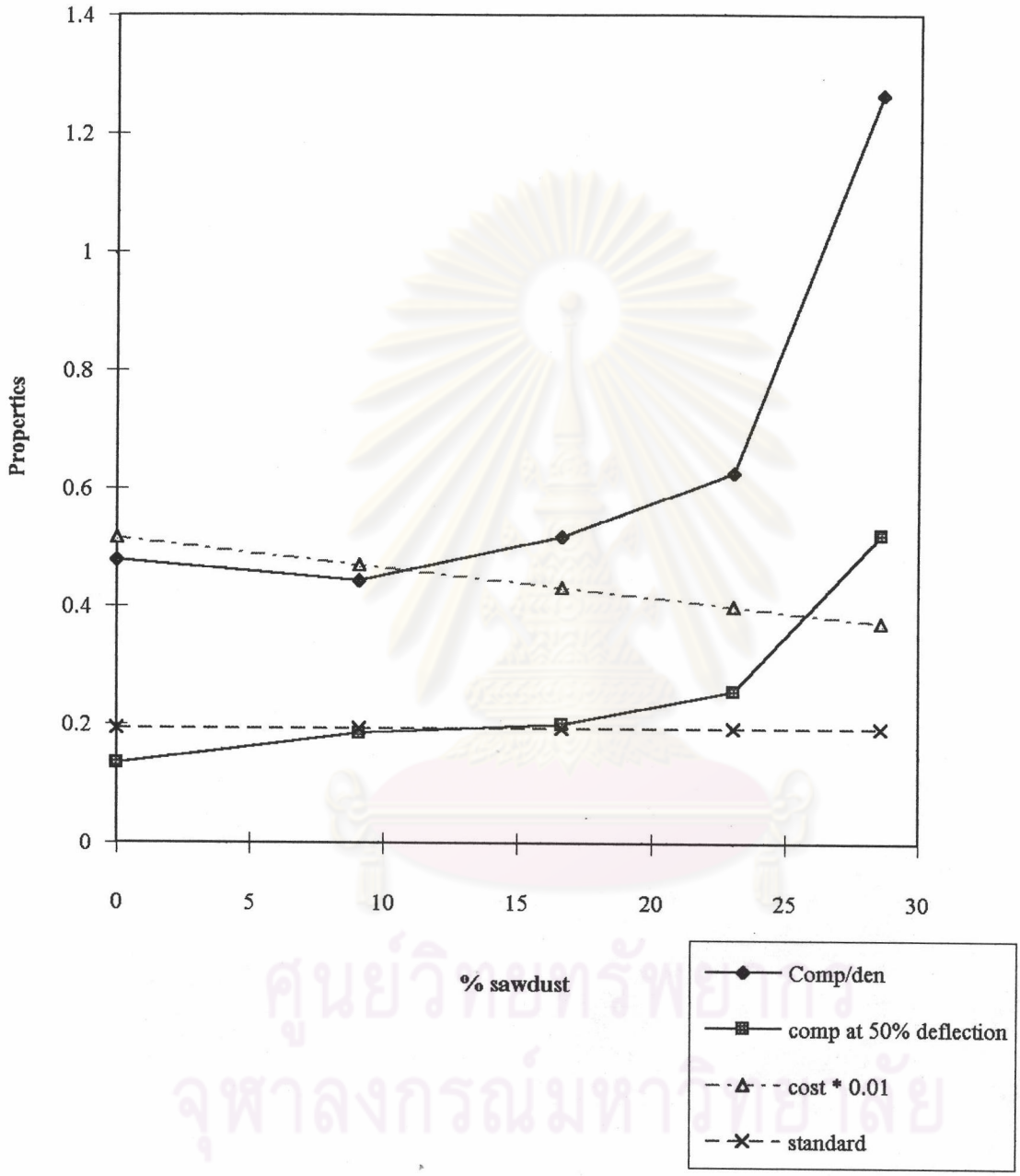


Figure 6.6 Relation between mechanical properties and estimate cost by various weight percentage of sawdust at a fixed % molasses of 20

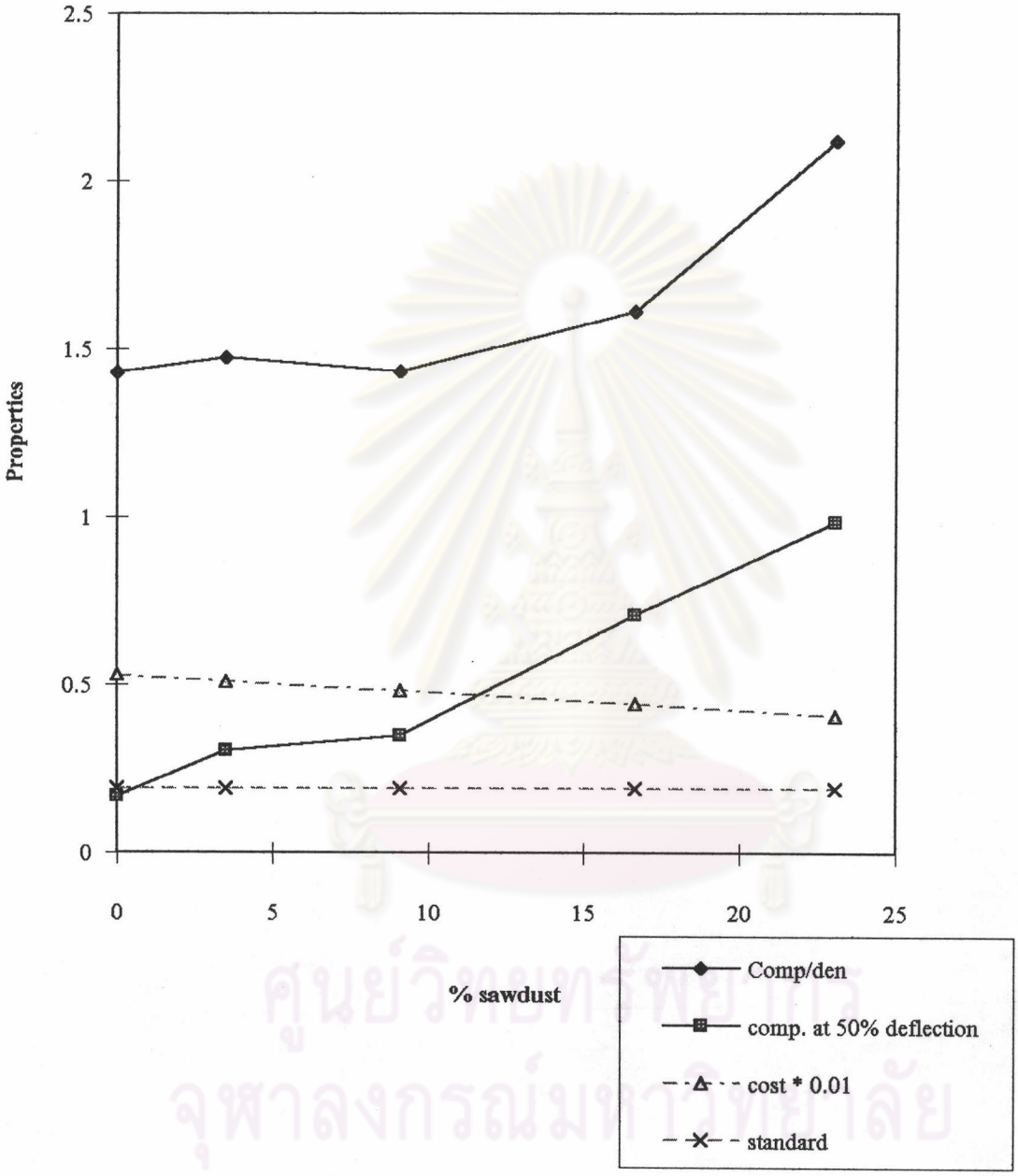


Figure 6.7 Relation between mechanical properties and estimate cost by various weight percentage of sawdust at a fixed % molasses of 35

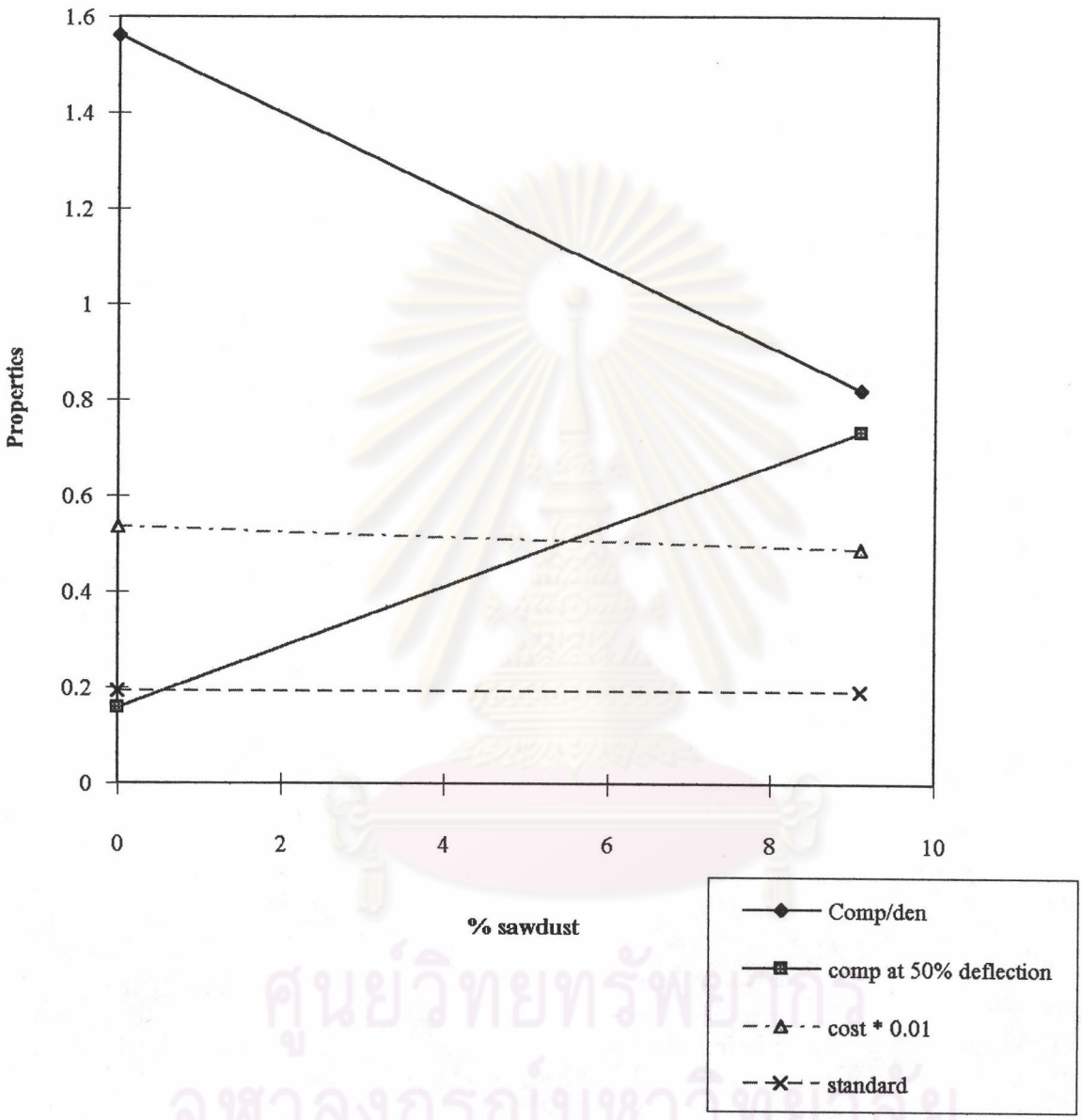


Figure 6.8 Relation between mechanical properties and estimate cost by various weight percentage of sawdust at a fixed % molasses of 50

6.1.3 Cost of filled-polyurethane

Material cost :	Polyether polyol	45	Bath/Kg.
	Polymeric MDI	80	Bath/Kg.
	Molasses	2	Bath/Kg.
	Husk	0.73	Bath/Kg.
	Sawdust	1.40	Bath/Kg.
	Dibutyltin diluarate	320	Bath/Kg.

Compositon of 9.09 % filler husk - polyurethane at % molasses of 20

Polyether polyol	47.31	weight percent
Molasses	11.83	weight percent
Polymeric MPI	31.76	weight percent
Filler (husk or sawdust)	9.09	weight percent

Compositon of 3.51 % filler husk - polyurethane at % molasses of 35

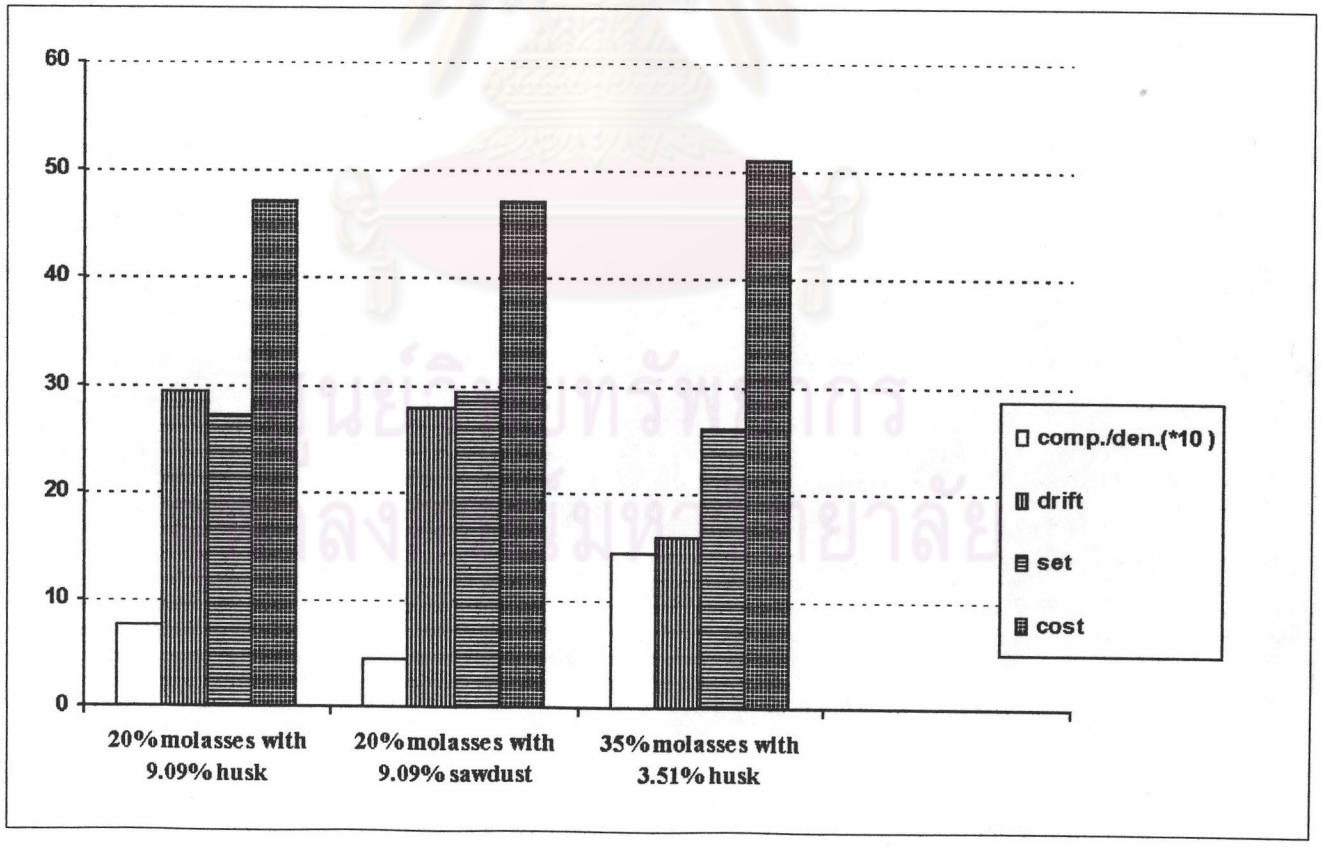
Polyether polyol	34.11	weight percent
Molasses	18.36	weight percent
Polymeric MPI	44.01	weight percent
Filler (husk or sawdust)	3.51	weight percent

At 9.09 % filler (husk or sawdust) of % molasses of 20 and 3.51 % husk of % molasses of 35, two products can be uesed for packaging. While cost of foam at 3.51% husk of % molasses of 35 is more expensive, but it gives a better propeties.

Table 6.9 Mechanical propeties and cost of product.

Product	density (ρ) ($g/cm.^3$)	compressive strength at 10% deformation (σ) (N/mm^2)	σ / ρ	Driff	Set	Cost (Bath / kg.)
20% molasses with 9.09% husk	0.1452	0.1060	0.7507	29.29	27.08	47.01
20% molasses with 9.09% sawdust	0.1448	0.0643	0.4441	27.89	29.30	47.07
35% molasses with 3.51% husk	0.0852	0.1220	1.4319	15.82	26.02	50.95

Figure 6.9 Mechanical propeties and cost of product.



6.2 Conclusion

Molasses has effects on mechanical properties as increasing compressive strength when % molasses in polyol increased, because the size of rigid block increase. Furthermore at % molasses of 60, the foam became brittle. Water in molasses acts as blowing agent, that decrease density of product when % molasses increased.

Filler (husk and sawdust) has effects on increasing compressive strength and density, and decreasing drift and set of foams with % molasses of 20 and 35. At % molasses 35, when percentage of sawdust is higher, drift and set began to increase. When the percentage of filler was too high, the product is so hard that cannot use as cushioning material.

Size of sawdust has effects on properties of the product, the fine sawdust can increase density and compressive strength more than the coarse.

According to this experiment, the suitable compositons of filled - polyurethane for used as packaging material are shown in table 6.9. At % molasses of 35 filled with 3.51 % of husk, the product is suitable for heavy duty and at % molasses of 20 filled with 9.09 % of either husk or sawdust, are suitable for light duty.