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CHARACTERISTICS AND STRENGTH EVALUATION OF THE MIXED MATERIAL OF FLY ASH FROM MUNICIPAL SOLID WASTE INCINERATOR AND THE RECYCLED POLYPROPYLENE

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Abstract : The purpose of research is to mix the fly ash from municipal solid waste incinerator in the recycled Polypropylene and to recycle. The specimen was produced by mixing 20 wt.% of MSWI fly ash at maximum in the recycled Polypropylene and the particle size analyzer, DSC, TGA, SEM and UTM instruments were used to analyze the physical chemical properties of the specimen.

As a result of measurement, the average particle size of MSWI fly ash was 18.08 ㎛. In TGA analysis, the temperature of specimen S-5 at 50% of weight decrease was risen by 7℃ higher than specimen S-1. In UTM measurement, specimen S-2 showed the maximum strength for tensile strength and specimen S-3 showed the maximum strength for flexural strength. But, impact strength was decreased according to the increasing proportion of MSWI fly ash. In conclusion, when the proper amount of MSWI fly ash was added to the recycled Polypropylene, thermal endurance, tensile strength and flexural strength could be increased, but impact strength was decreased.

Key Words : MSWI fly ash, Rcycled Polypropylene, Recycle, Specimen

INTRODUCTION

According to population growth and the elevated standard of living as a result of industrialization and urbanization, the occurrence amount of municipal waste is tending upward rapidly. Although the municipal waste has been treated by landfill mainly so far, the difficulty of securing the location for the reclaimed ground and the second environmental pollution by leaching water are problems. When compared to the direct landfill of municipal waste, incineration can decrease the volume of waste by 90%, so it has an effect to extend the using term of the reclaimed ground.[1)]

In 2003, the total amount of waste taken in large sized incinerators in Korea was reached to 2.1 million tons and currently, the construction of incinerators and treatment by incineration are increasing drastically due to the decreased volume of such waste, collection of useful energy and shortage of reclaimed ground. The incinerated ash of waste taken in incinerator is about 370 thousand tons which is 17.6% of volume before incineration and such an ash is divided into bottom ash and fly ash. Bottom ash and fly ash depend on landfill mostly and landfill cost is also about 9.8 billion won which is almost 12.7% of operating expenses of whole incinerators. In addition, the recycling proportion of bottom ash and fly ash is 4.8%, 0.7% respectively (based on 2003) and it's decreasing every year actually. So, since it is expected that the treatment of incinerated ash will be raised

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to the main environmental problem, the study of proper treatment for them is urgent.[2)]

The recycling of bottom ash to road construction material is proceeding actively in Europe. In Korea, the study using incinerated ash of paper sludge for construction and engineering work materials is coming along and recently, the study utilizing fly ash to substitute for cement is in progress.[3-5)]

Plastic is used with general and industrial purpose variously with it's excellent characteristics and the amount of production and consumption are increasing by geometric progression. While the consumption of plastic is increasing rapidly, the recycling proportion is just 26.3% and reclamation and simple incineration among recycling methods are over 70%. According as the recycling responsibility rate was noticed on 'law regarding nursing resources and promoting recycling' announced by the Ministry of Environment, the amount to be recycled will be increased more and more.

Polypropylene, which occupies the highest portion of whole plastic as 29.2%, has an excellent tensile and flexural properties, but due to low impact strength, it is used by mixing with rubber to improve it and rubberization lowers tensile and flexural properties. To prevent this lowering, the improvement by adding micro and nano-particle reinforcing agent to poly-propylene is being studied recently.[6-9)]

Therefore, this research has purposes to produce specimen to utilize fly ash for filler of the recycled polypropylene as a scheme of waste recycling and to evaluate the physical chemical properties and mechanical properties of specimen.

MATERIALS AND METHODS

The fly ash used on experiment was collected from municipal solid waste incinerator of C area whose size is 200 ton/day. The collected sample was dried naturally and then, dried in dry oven at 105℃ for 24 hr to be used on experiment.

The recycled Polypropylene was produced by the recycled plastic manufacturer in K city. Pellet is 0.3×0.2×0.4 cm size with the shape of black cylinder and to prevent the transformation during dry, it was used after dry at low temperature (60℃) for 6 hours. The pure Polypropylene is white, but many additives are used on production.

Since various kinds of products with various colors were mixed in the process of selection for recycling Polypropylene and recycling, the color and characteristics of recycling products can be different according to the production time.

Production of specimen

It is known that it is important to make particles distributed equally for production of specimen in case of mixing the powder particle with plastic. To produce specimen through injection after pressing out is able to disperse the particle of fly ash more effectively than to produce specimen by catapult at one time. In case of fly ash, since it has the characteristics to form a mass by absorbing moisture in the air, we used fly ash after dry completely. After mixing the completely dried fly ash and the recycled PP pellets equally as much as possible, we produced new pellets on condition of 200℃ / 2500 rpm by using an extruder and produced 3 kinds of specimens required to plastic strength experiment by compounding these pellets with catapult (SPF-100, Hyundai Precision Industry) at 200℃. Figure 1. shows the picture of specimen produced.

Also, we produced specimen by increasing the mixture ratio of fly ash by 5 wt.% between 0 ~ 20 wt. The reason why the ratio of fly ash doesn't not applied more than 20 wt% is that since volume rate is almost equal in case of 20 : 80 in weight rate, the additives like coupling agent is necessary for mixing the more. In this experiment, we molded by mixing simply without using any additive. Table 1 shows the mixture ratio of the recycled PP and fly ash on the production of specimen.

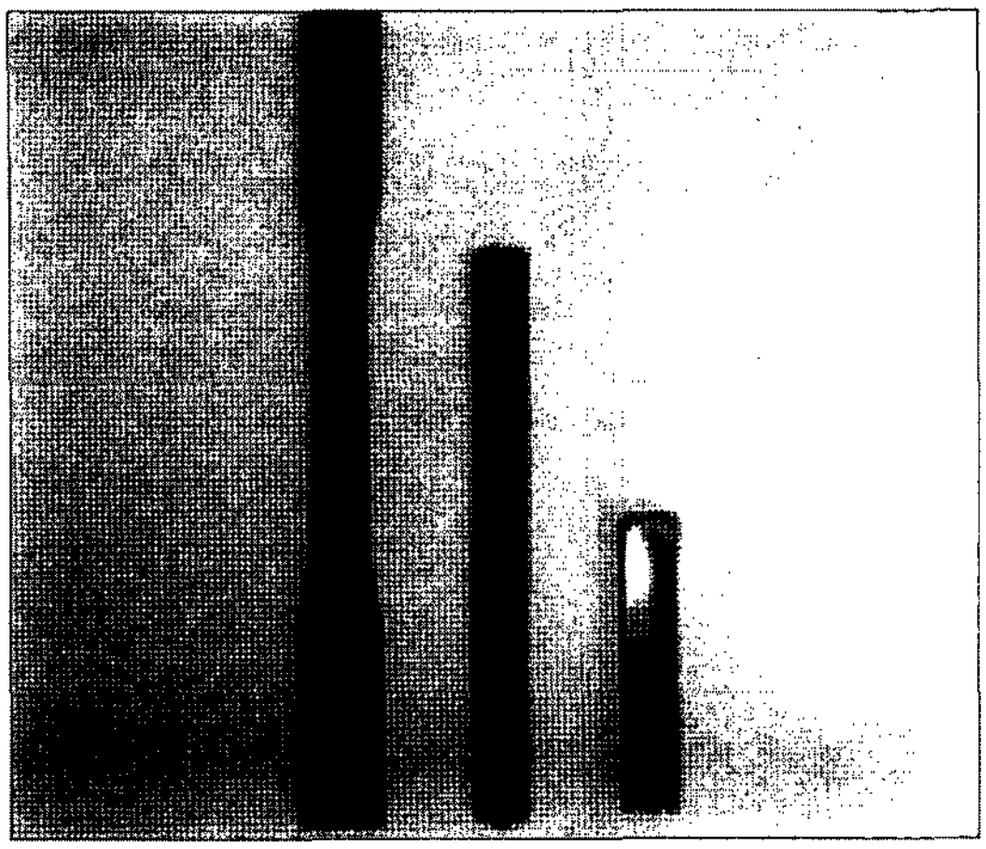


Figure 1. The photograph of specimen

Table 1. mixture ratio of the recycled PP and fly ash on the production of specimen

<unit : wt.%>

MSWI fly ash	0	5	10	15	20
RPP	100 (S-1)	95 (S-2)	90 (S-3)	85 (S-4)	80 (S-5)

Chemical composition

To analyze the chemical composition of MSWI fly ash, we used EDS analyzer. We analyzed to compare the composition of fly ash with Hwangto, clay and white clay among the materials which could be got easily around.

Particle size and distribution

The distribution of fly ash particle was analyzed by Particle Size Analyzer (malvern Instruments) and it is the method to evaluate the particle size by measuring the diffusion of He-Ne laser beam after dispersing the fly ash particle into the distilled water.

Thermal characteristics

To study thermal characteristics, the specimen was measured by using thermal gravimetric analyzer (TGAQ50 (TA Instrument)) and differential scanning calorimeter (DSC2010 (TA Instrument)). Thermal gravimetric analyzer measures the weight change under 10 μg by function of temperature and time, and we found the thermal stability according to beam balance principle. Also, we could verify the components of blend or compound based on thermal stability of each component. Differential scanning calorimeter can examine the thermal transition of macromolecule. The degree of purity of polymer sample can be measured by observing the appearance of additional peak or migration of curve.

Section analysis

We took a photograph the section of specimen which was produced by the fixed mixture ratio of fly ash and the recycled PP in size of more than 500 times, using SEM (JSM-6400) and analyzed the difference on section according to addition of fly ash and particle shape.

Mechanical strength

Mechanical strength was measured with 3 kinds of specimen produced by mixture ratio. Tensile strength (ASTM D638) is an important measure to indicate the strength of material and Universal Testing Instrument (STM-10) was used. We measured tensile strength, which is the maximum stress to endure in axis direction by pulling both sides of specimen, and tensile modulus. Flexural strength is the maximum value that the load isn't increased by applying flexural power to curve specimen and was measured by ASTM D790, using Universal Testing Instrument (STM-10). For impact test, impact tester of Zwich was used according to ASTM D4812-93. Impact test is used widely to evaluate the resistant ability of material under high-speed impact weight. Since impact strength is affected a lot by distribution or location of filler rather than notch size, we proceeded Izod impact test according to impact test method of specimen without notch.

Extraction of heavy metals

For extraction of heavy metals, we analyzed by KSLT which is used in Korea and TCLP which is used in the US. Analysis items are 6 kinds of Cu, Pb, Cd, As, Hg, Cr which are

Table 2. method of extraction of heavy metals

Method / Condition	KSLT	TCLP
Liquid Solution (pH)	HCl (pH: 5.8~6.3)	Acetic acid (pH: 4.93±0.05)
Liquid:Solid Ratio	10:1	20:1
Size of Sample	0.5~5 ㎜	<9.5 ㎜
Temperature	21℃ (room temp.)	22.3±3
Agitation Apparatus	Shaking Stroke: 4~5 ㎝ Speed: 200 rpm	Shaking Stroke: 4~5 ㎝ Speed: 30 rpm
Leaching time	6 hr	18 hr
Filter size	1 ㎛ GFF	0.8 ㎛ GFF

included in the waste process testing method and the detailed analyzing method is shown on table 2.

RESULTS AND DISCUSSION

Chemical composition of MSWI fly ash

Table 3 gives the analysis result of chemical composition of MSWI fly ash as well as other ceramic materials. Those components are included in order of Chloride (39.61%) > CaO (36.09%) > Na_2O (13.20%) > K_2O (5.70%) > SiO_2 (3.53%) > Al_20_3 (0.94%) > MgO (0.68%) > P_2O_5 (0.25%) and the difference of MSWI fly ash from other materials was analyzed that the CaO is higher and SiO_2, Fe_2O_3 content is lower relatively. The reason of high content of CaO is because huge amount of quicklime is used during incinerating process.

Distribution of particle size of MSWI fly ash MSWI fly ash is alkaline with pH 10.4. As the addition rate of fly ash to the recycled PP increases, pH of specimen also increases and it is considered that the part of fly ash was eluted and it gave affect.

The particle size of material filled in plastic have a big effect on characteristics of plastic, especially for strength. It is known that smaller particle size makes better strength, but it costs a lot to make particle small artificially.

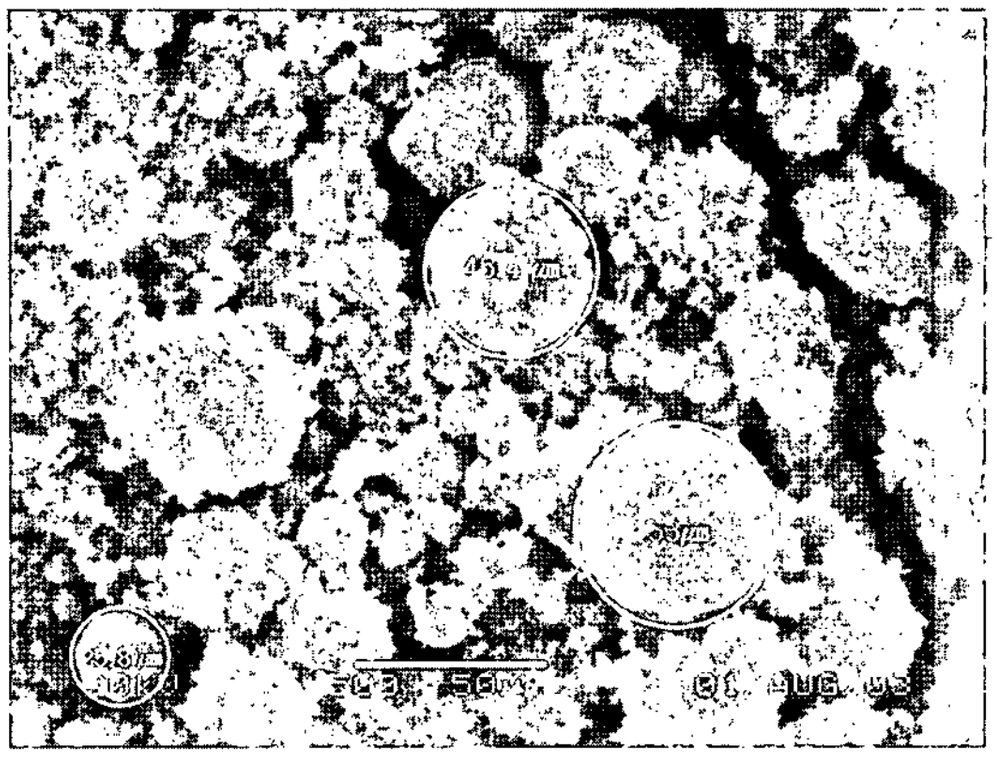
Figure 2. is photograph of MSWI fly ash taken by SEM. The particles of fly ash composed with inorganic matters mainly have a spherical shape and have various sizes of particles though they are small. Figure 3. is the analysis result of size distribution of MSWI fly ash particles. As a result of analyzing, the particle size range is 1.2~166 ㎛, size less than 4.18 ㎛ is under 10%, size less than 53.35 ㎛ is under 90% occupying majority and the average size was 18.08 ㎛. As a result of analyzing the size distribution, it is considered that MSWI fly ash will affect the strength improvement when it is mixed with the recycled PP in proper ratio.

Thermal Characteristics

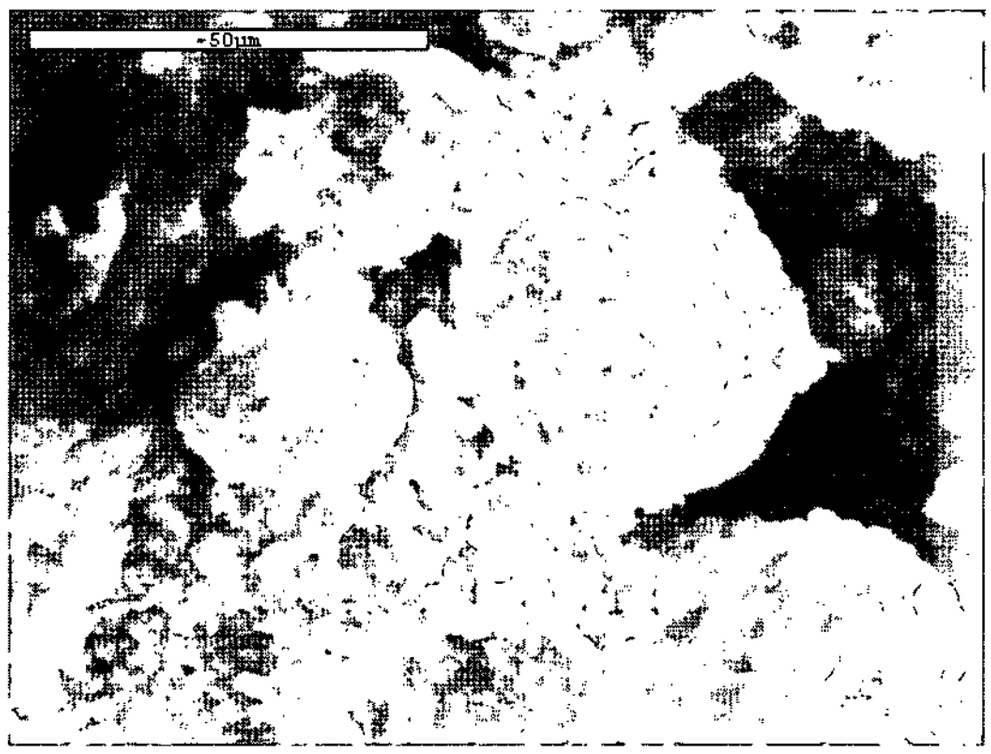
DSC and TGA were used to analyze the thermal characteristics of fly ash. Figure 4. shows the DSC result of pure PP and the specimen. Generally, peak point means melting

Table 3. result of chemical composition of MSWI fly ash and other ceramic materials

Component / Kind	CaO	SiO_2	TiO_2	Fe_2O_3	MgO	Al_2O_3	Na_2O	P_2O_5	SO_3	K_2O	Chloride
MSWI fly ash	36.09	3.53	·	·	0.68	0.94	13.20	0.25	·	5.70	39.61
Clay	0.70	62.93	1.14	4.33	1.56	23.44	2.42	·	0.63	2.85	·
Kaolinite	6.04	52.12	0.04	1.52	1.64	33.08	4.76	·	·	0.80	·
Montmorillonite	0.15	53.04	0.97	11.51	1.79	23.11	1.60	·	·	7.83	·
Terra alba	0.08	82.85	·	1.75	0.27	7.67	4.43	·	·	2.95	·



(a) × 500



(b) × 15000

Figure 2. SEM photograph of MSWI fly ash.

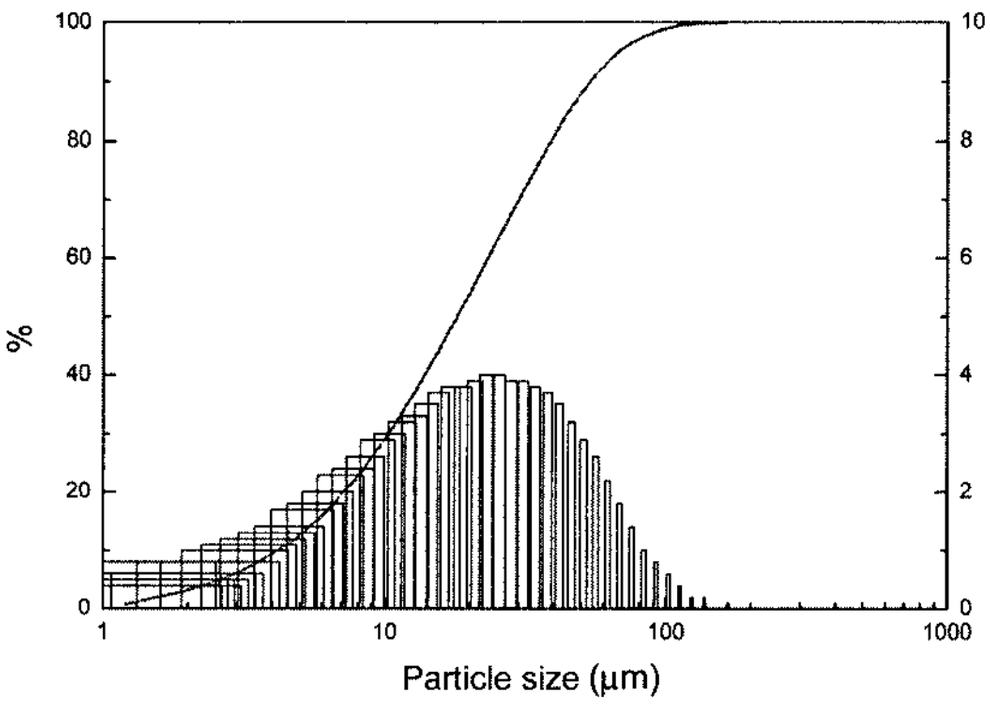
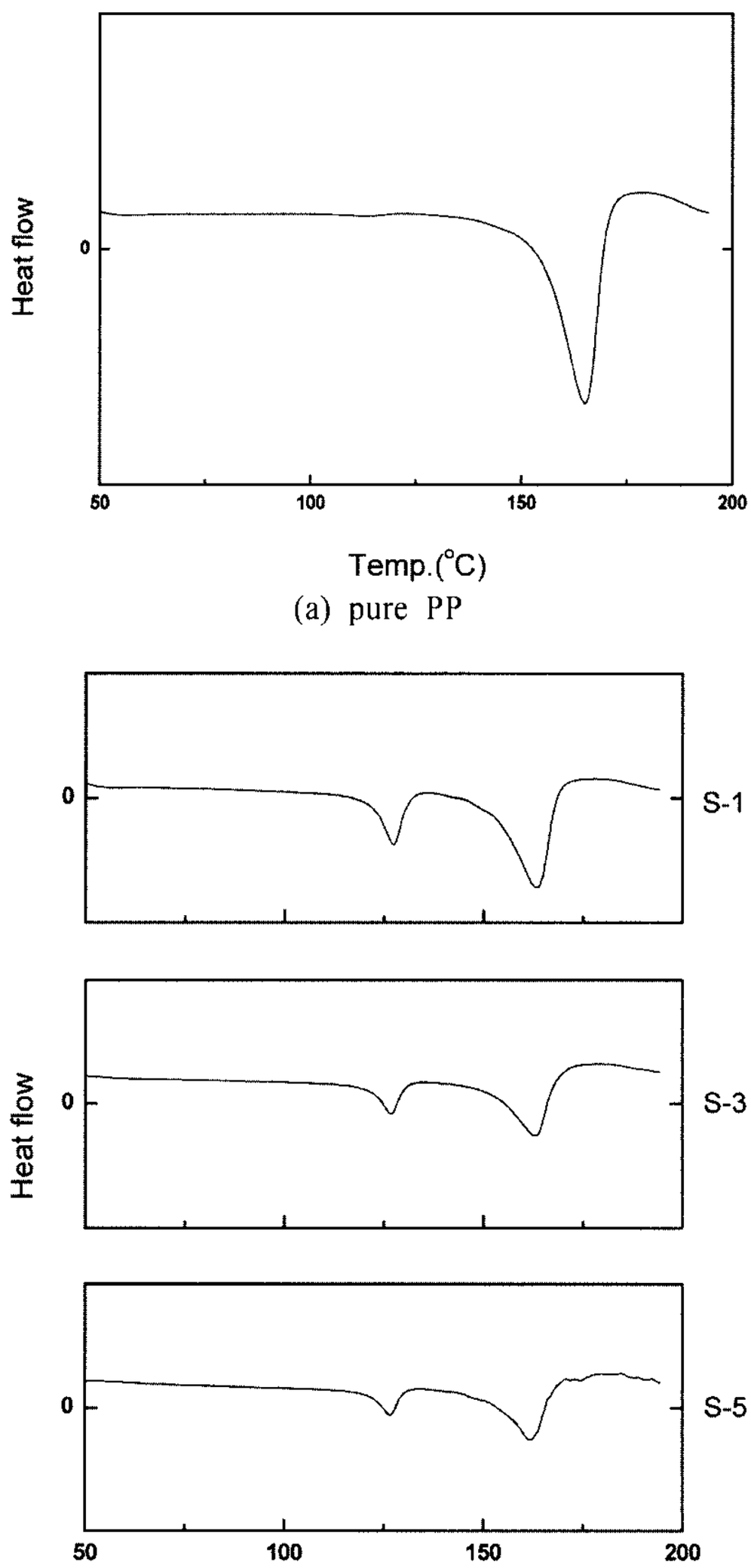


Figure 3. Distribution of MSWI fly ash particles.

temperature on DSC graph and the double peak of the S-1 in Figure 4. means that the recycled PP is not pure and mixed with different kinds of plastics.

The melting point of pure PP is 165.1℃ and has one peak. In case of the recycled PP, it has two peaks at 127.4℃ and 163.3℃. It is judged that the distribution for recycling plastic is not perfect and the complete distribution was not done in sorting process, so the recycled PE was mixed. DSC result of specimen S-2,3,4,5 showed all double peak and the peak temperature difference on each graph was not so changed, less than ± 0.5℃. Analyzing through these results, specimens which were produced with



(a) pure PP

(b) specimen S-1,3,5

Figure 4. DSC result of pure PP and the specimen.

using MSWI fly ash as a filler to the recycled PP couldn't show the change on melting temperature.

TGA analysis was conducted to study the thermal stability of specimen. Figure 5. shows the weight decreasing tendency according to increasing temperature and also displays the thermal pyrolysis temperature of each specimen. When the weight of specimen S-1 was decreased by 50%, temperature was 461℃ and in case of S-5 containing 20 wt.% of fly ash, it was 468℃, increasing by 7℃. In addition, while S-1 only left 3.2% of total weight among residue after finishing pyrolysis, S-5 left 21.3% of residue. The reason is judged that the weight loss of MSWI fly ash was less than 30% at 500℃ on DSC graph and the melting temperature is much higher than the recycled PP. It is also considered that the pyrolysis temperature of S-5 was risen by adding MSWI fly ash whose main composition is inorganic to recycled PP.

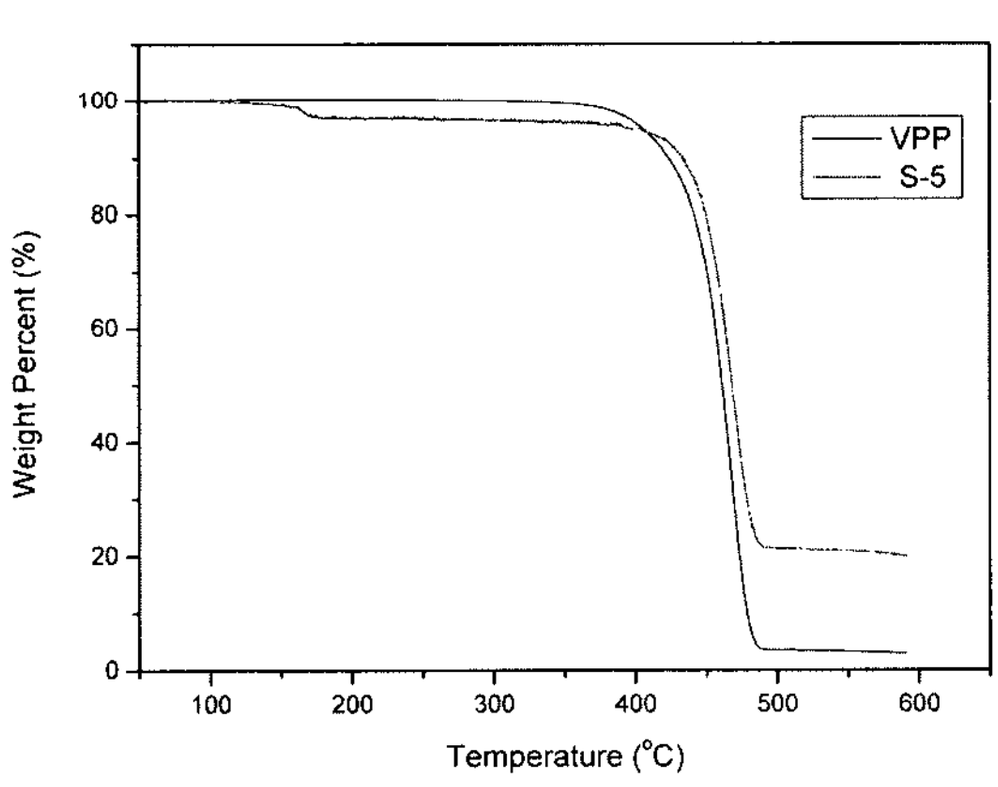


Figure 5. TGA result of the specimen S-1 and S-5.

Section Analysis (SEM)

Figure 6. shows the photograph of section of specimen S-1 taken by SEM. There is black part on photo for section of S-1 and when comparing the recycled PP to pure PP, there are shown black part a lot because the high molecular crystal is not perfect. Figure 7, 8 are photo for section of S-3 and S-5 respectively taken by SEM. Amorphism parts were disappeared a lot, different from Figure 6. and density was increased, but the pores were observed. It means that although several steps underwent to distribute particles at maximum, it was not perfect.

Especially in case of specimen S-5, we can observe many lumps of particles and pores in the photo. Therefore, to mix lots of fly ash, it is necessary to produce particles after chemical treatment to disperse them completely, but since it costs a lot, the economical evaluation should be ahead of to apply to actual products.

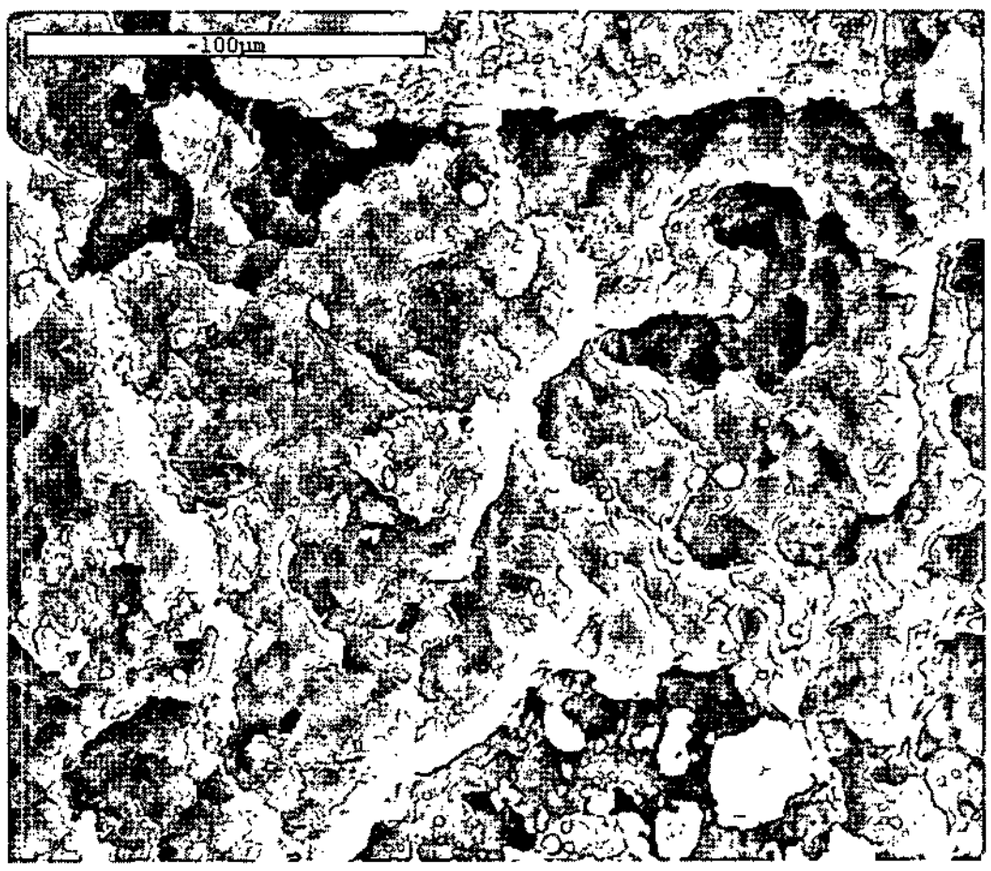


Figure 6. Photograph of section of specimen S-1.

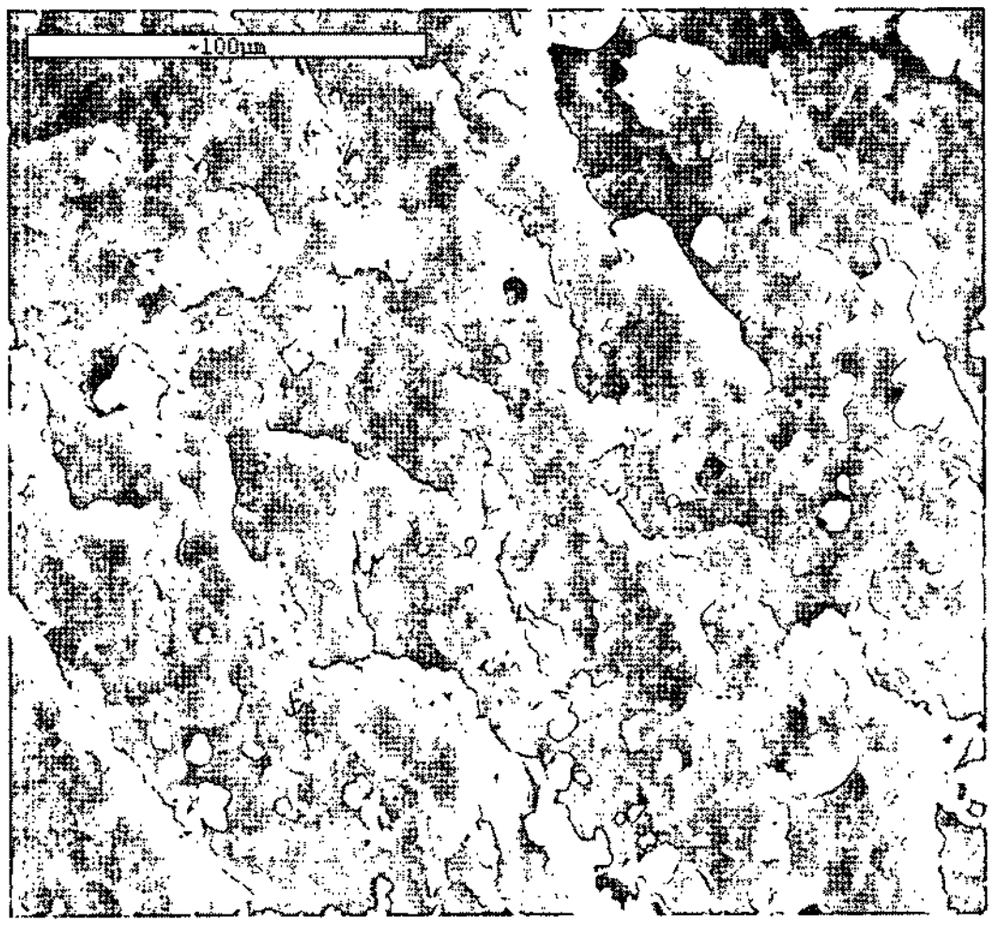


Figure 7. Photograph of section of specimen S-3.

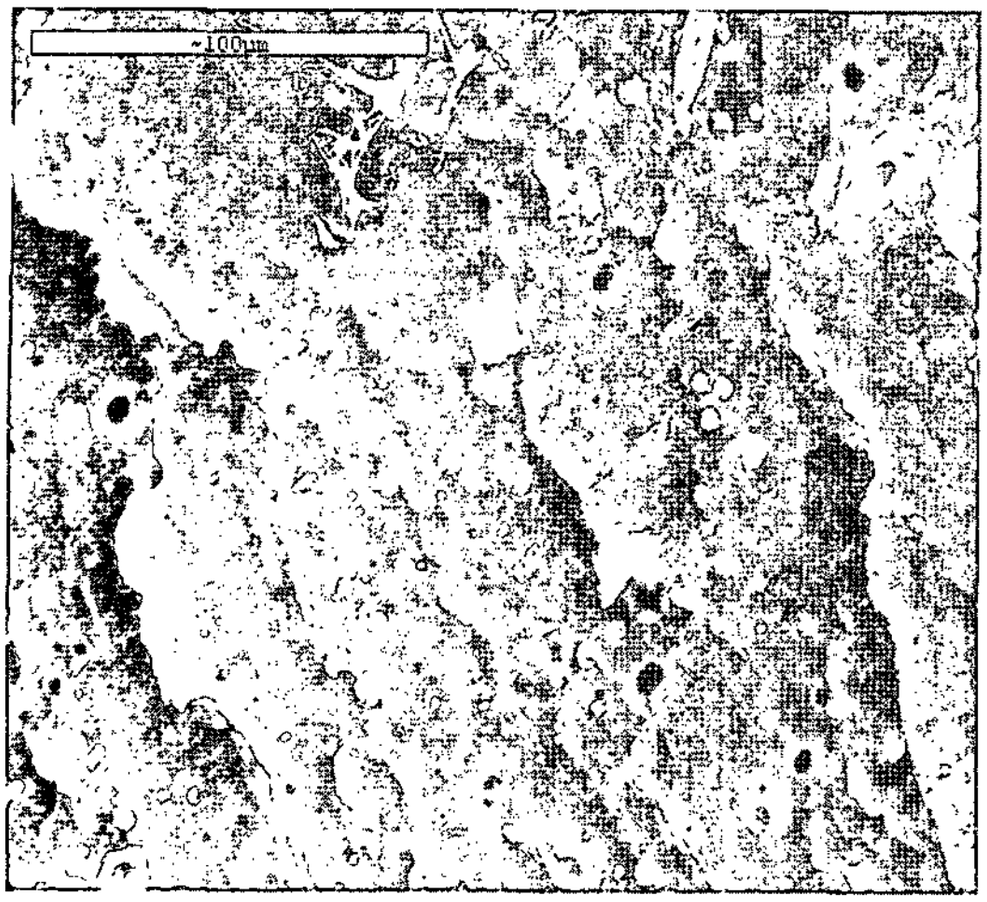


Figure 8. Photograph of section of specimen S-5.

Mechanical strength

Figure. 9, 10, 11 show the result of tensile strength, flexural strength and impact strength of each specimen. For tensile strength, specimen S-2 had the highest value at 45.3 MPa and for flexural strength, specimen S-3 was the highest at 1.32 MPa. On the other side, for impact strength, it was decreased by adding fly ash. When pulling both sides of specimen, the initial slope in relation of stress and transformation is called the modulus of tensile elasticity and it is displayed on table 4. For the tensile modulus, S-2 had the highest value, same as tensile strength. By adding a certain quantity of fly ash, tensile strength and flexural strength, which are increased gradually during measurement, were increased and impact strength was not improved with PP who has defect that it is weak under impact.

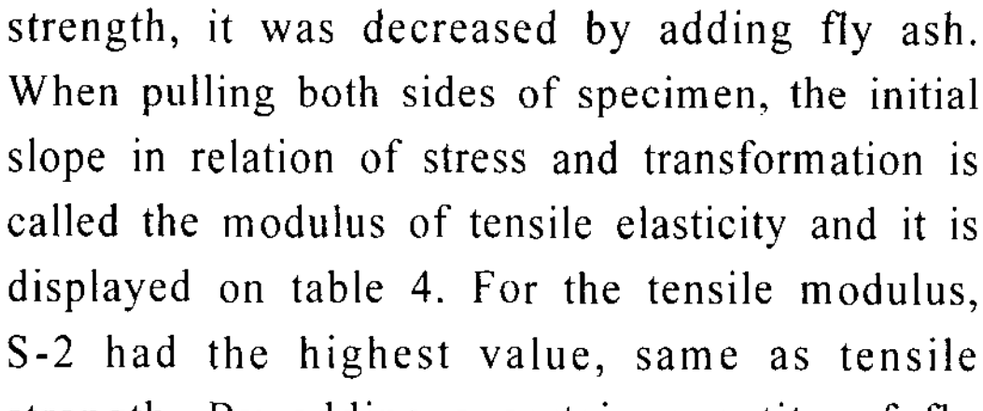


Figure 9. Tensile strength of the specimen.

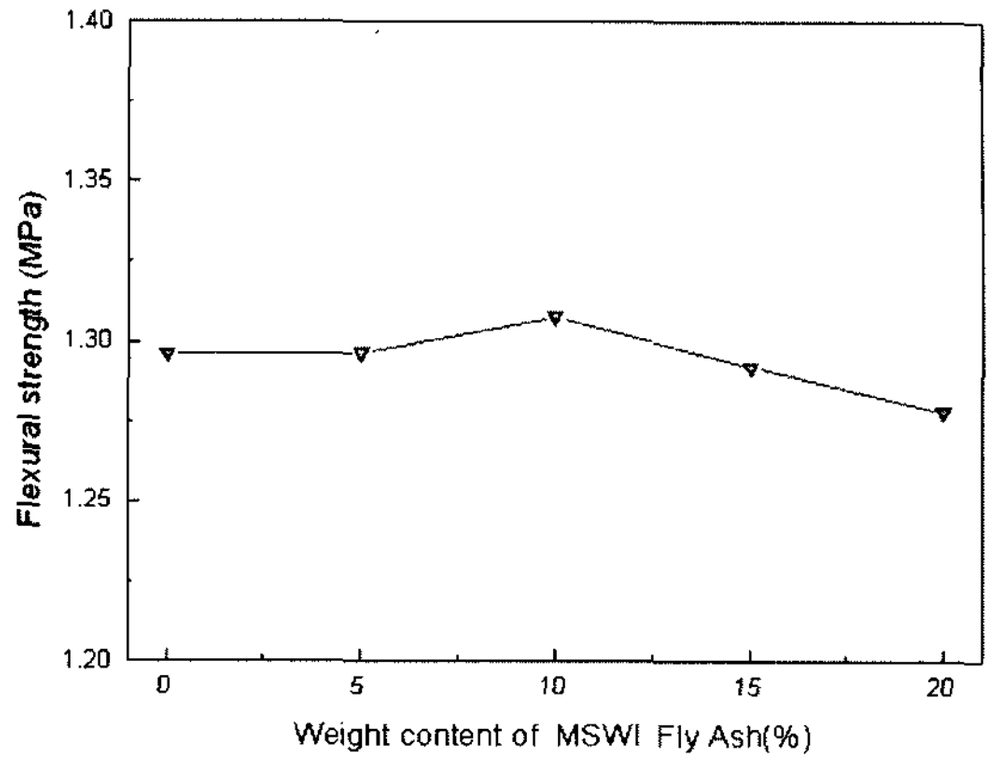


Figure 10. Flexural strength of the specimen.

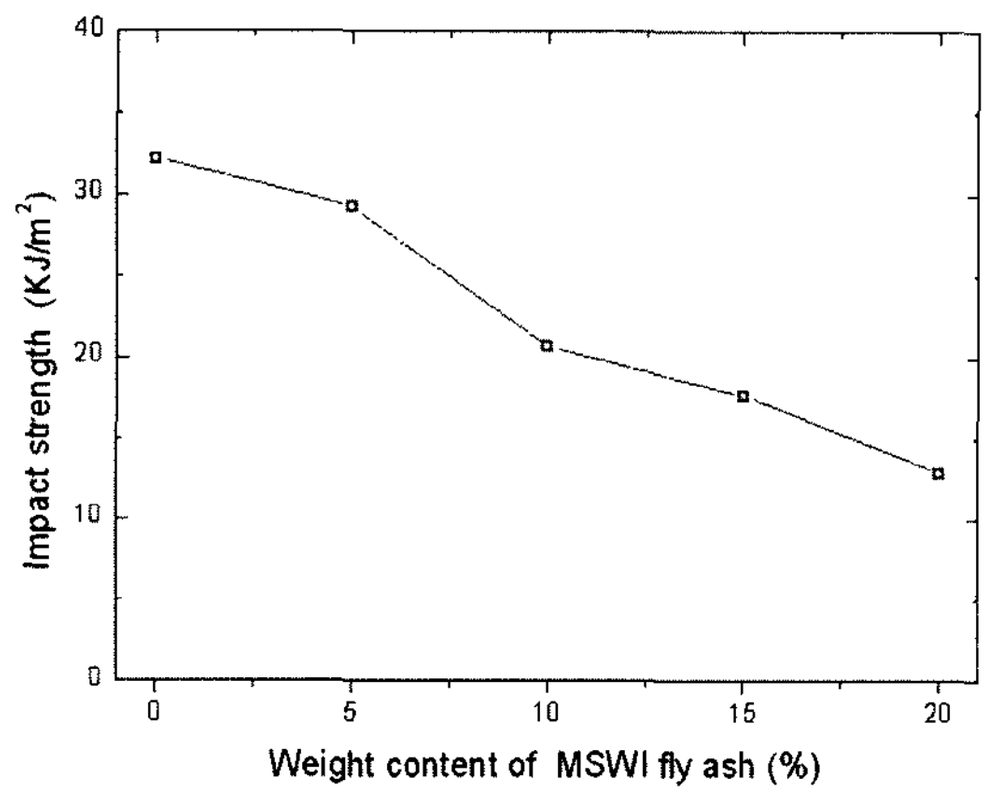


Figure 11. Impact strength of the specimen.

Table 4. Tensile modulus of the specimen

<unit : MPa>

Specimen	S-1	S-2	S-3	S-4	S-5
Tensile strength	1354.3	1398.1	1353.8	979	1059

When generalizing the analysis result by and large, for section analysis, specimen S-1 was the best to mix when producing by simple mixture and for thermal characteristics, although pyrolysis temperature was risen, there was no difference between S-1 and S-5. In strength evaluation, S-2 and S-3 showed the highest strength for tensile strength and flexural strength respectively, but when considering the producing technique, the mixture of 5 wt.% fly ash will

Table 5. Result of extraction of heavy metals

<Unit: mg/L>

Item \ specimen	S-1		S-3		S-5		Standard	
	KSLT	TCLP	KSLT	TCLP	KSLT	TCLP	KSLT	EPA
Cr	ND	ND	ND	ND	ND	ND	1.5	5.0
Cu	0.006	0.008	0.009	0.014	0.087	0.054	3.0	-
As	0.22	0.51	0.26	0.65	0.37	0.69	1.5	5.0
Cd	0.004	0.006	0.035	0.037	0.319	0.305	0.3	1.0
Hg	ND	ND	ND	ND	ND	ND	0.005	0.2
Pb	ND	ND	ND	ND	ND	ND	3.0	5.0

be the most efficient. However, it is considered that the mixture of several materials improving each characteristics will be more pertinent to improve all characteristics rather than mixing only MSWI fly ash.

Extraction of heavy metals

For extraction of heavy metals, as a result of analyzing S-1,2,3,4,5 mixed with the recycled PP and fly ash by dividing to KSLT method and TCLP method, Cr, Hg and Pb were not detected and other items satisfied the permissible level. *Only in KSLT method, Cd of S-5 was* exceeded the level. Although the permissible level was satisfied, there was tendency that the detected amount was increased according to increasing rate of MSWI fly ash. And, in the result of pH measurement, it was confirmed that the part of fly ash was eluted. Therefore, it is judged that it is difficult to prevent elution of heavy metals only by mixture of the recycled PP with MSWI fly ash and that it is necessary for the appropriate pre-treatment technique and the high temperature molding technique of MSWI fly ash.

CONCLUSIONS

1. MSWI fly ash has a spherical shape, the particle size is in the range of 1.2 ㎛ ~ 166 ㎛ and the average particle size is 18.08 ㎛. Therefore, when adding the proper amount to the recycled PP, the strength improvement can be expected.

2. On DSC graph, the melting temperature of each specimen was almost not changed by addition of MSWI fly ash, but in TGA analysis, specimen S-5 was improved on pyrolysis characteristics than S-1. It is considered that it will be affected by increasing rate of MSWI fly ash whose main component is inorganic.

3. In SEM analysis, the crystal got better and density was increased by adding fly ash, but according to adding fly ash a lot, it was lumped and the pores were caused. It is the result of simple mixture and it is not pertinent *to mix a lot of amount.*

4. In strength evaluation, S-2 and S-3 showed the highest strength for tensile strength and flexural strength respectively, but when considering the producing technique, it is judged that specimen S-2 will be the most efficient.

5. As a result of experiment for extraction of heavy metals by KSLT method and TCLP method, when adding the appropriate ratio of fly ash, the permissible level could be satisfied, but for practical use, the pertinent pre-treatment of MSWI fly ash is required.

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