UTILIZATION OF WASTE TIRES AS FUEL FOR CEMENT PRODUCTION

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1. INTRODUCTION

Japan has an acute land shortage and the disposal of waste tires, whose numbers increase annually, is becoming a social problem. Various disposal methods have already been developed. However, mere disposal should not be considered in a country lacking in natural resources. It is a matter of urgency that a practical method for recycling the resources be developed. True, various recycling techniques, such as pyrolysis and low-temperature crushing are being researched energetically, but it is expected that considerable time will be required before they are established on a practical scale.

As a large consumer of energy, the cement industry has been making incessant efforts to develop energy-saving techniques and to diversify the fuels used. During the last 20 years, the cement manufacturing process in Japan has changed from a wet to a dry process. Of the dry processes, the adoption of large New Suspension Preheater (NSP) kilns, equipped with suspension preheater type heat-exchange facilities, and a precalciner superior in productivity and thermal efficiency, has significantly reduced the heat consumption per kg of cement produced (Fig. 1). However, sharp rises in the cost of fuel have forced the industry to speed the development of substitute fuels.

![Heat Consumption](image)

Fig. 1. Decrease of average heat consumption.

Under such circumstances, Nihon Cement Co. Ltd. (NC) and Bridgestone Tire Co. Ltd. (BS) have co-operated in the development of a technique for utilizing waste tires as an auxiliary fuel for cement production. The system thus established has satisfactorily met the needs of the tire industry in disposing of large numbers of used tires economically without causing pollution and in reducing the amount of fuel used by the cement industry.

The fact that NC and BS have surmounted the barriers existing between the two different industries and have established an overall resource recycling system satisfying the twin
objectives of waste disposal and conservation of energy has, it is believed, brightened the future for the development of resource recycling systems.

2. GENERATION OF WASTE TIRES, DISPOSAL AND RECYCLING

Current generation of waste tires in Japan is shown in Table 1. From the Table the number of tires produced can be estimated as approximately 50,000,000 annually. Figure 2 shows the treatments of these waste tires. It can be noted that 75% of the numbers produced are utilized: Powder rubber and reconditioned rubber 36.6%; Fish shelter, dyke material, used in original form 15.5%; Reconditioned tires 12.6%; Export 10.5%.

2.1 Recycling in original form
(1) Tire fish shelter. In Japan, the technique of utilizing waste tires as artificial fish shelter material started in 1971, and 330,000 tires have so far been used for this purpose.
(2) Dyke material. Waste tires are piled at the slope of the hill to prevent landslides. Vegetation is sometimes planted in the vacant spaces of the tires to provide additional resistance. Approximately 500,000 tires have been used for this purpose in Japan.
(3) Others. Other uses are: gunwale protection, tree protection, playground facilities, mats for riparian works.

2.2 Recycling after physical or chemical treatments
(1) Powder rubber. After crushing waste tires, they are pulverized into powder form and used for making plate-shaped processed items, reconditioned rubber and material for rubber asphalt.
(2) Pyrolysis. This is a method of obtaining gas, oil and carbon by dry distillation of waste tire at a fixed temperature. This has been considered one of the most promising recycling techniques. However, its two drawbacks (high cost of the facilities and variable quality of the recycled product) suggest that it is not necessarily the best at this stage.

3. EVALUATION OF WASTE TIRES AS FUEL

3.1 Waste tires as fuel
Chemical analysis and calorific values of waste tires and of the main fuels used in the cement industry are given in Table 2. The combustible components, carbon and hydrogen, contained in

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</thead>
<tbody>
<tr>
<td>Disused when tires are changed</td>
<td>30 357</td>
<td>32 257</td>
<td>34 157</td>
<td>36 057</td>
<td>37 956</td>
<td>39 855</td>
</tr>
<tr>
<td>Disused when cars are scrapped</td>
<td>12 338</td>
<td>13 515</td>
<td>14 120</td>
<td>15 407</td>
<td>16 166</td>
<td>16 930</td>
</tr>
<tr>
<td>Total</td>
<td>42 695</td>
<td>45 772</td>
<td>48 277</td>
<td>51 464</td>
<td>54 122</td>
<td>56 785</td>
</tr>
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Table 2. Properties of fuels and tires

<table>
<thead>
<tr>
<th></th>
<th>Tire</th>
<th>Heavy Oil</th>
<th>Coal</th>
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<tbody>
<tr>
<td>Moisture %</td>
<td>—</td>
<td>—</td>
<td>2.6</td>
</tr>
<tr>
<td>Carbon %</td>
<td>89.2</td>
<td>86.0</td>
<td>69.0</td>
</tr>
<tr>
<td>Hydrogen %</td>
<td>7.3</td>
<td>11.1</td>
<td>4.0</td>
</tr>
<tr>
<td>Sulphur %</td>
<td>1.8</td>
<td>2.4</td>
<td>0.4</td>
</tr>
<tr>
<td>Nitrogen %</td>
<td>0.2</td>
<td>0.3</td>
<td>1.3</td>
</tr>
<tr>
<td>Ash %</td>
<td>1.5</td>
<td>—</td>
<td>15.2</td>
</tr>
<tr>
<td>Calorific value (kcal/kg)</td>
<td>8970</td>
<td>10 350</td>
<td>6500</td>
</tr>
</tbody>
</table>

Fig. 2. Disposal of waste tires.
tires are present in amounts similar to those in heavy oil. The calorific value of waste tires varies somewhat depending upon the ratio of fibrous materials and steel contained. In practice, it is found to rank between oil and coal and is usable as a fuel for manufacturing cement. Further, the relatively low level of sulphur and nitrogen, which might cause pollution, is of advantage in utilizing waste tires.

3.2 Burning properties of waste tires

The burning properties of tires are shown in Fig. 3. As is clear from this figure, tires ignite at 300 - 350°C and burn rapidly. When the temperature exceeds 450°C, the carbon contained in the tires starts burning and is burnt almost completely at 650°C, leaving only ash and steel.

4. APPLICATION OF WASTE TIRE IN THE CEMENT MANUFACTURING PROCESS

4.1 Outline of the cement manufacturing process

As shown in the flow sheet of a cement production line (Fig. 4), cement is manufactured by:
(a) mixing and crushing of raw materials — limestone, clay, silica sand, and iron material,  
(b) feeding the raw meal thus obtained into a rotary kiln, burning a large amount of fuel,  
and sintering at a temperature of about 1500°C to obtain clinker,  
(c) addition of gypsum and pulverizing of the mixture.

By virtue of differences in the methods of grinding and preparing raw materials, cement manufacturing processes have two main classifications: *viz.* wet-process and dry-process. As stated previously, a suspension preheater kiln, with precalcin, is mainly used in Japan.

### 4.2 The use of tires

Utilizing tires has the following advantages for the cement manufacturing process:

(a) The cement burning process is a closed system where the dust removed from the exhaust gas by an electrical precipitator is recycled into charge material. Thus, the ash in tires is not discharged from the system. Moreover, sulfur contained in tires will be absorbed by the raw materials of cement and will not create harmful SO₂;  
(b) The temperatures within the process will reach maxima of 1800°C in the burning gas and about 1500°C in the clinker. Therefore, tires fed to the kiln will burn completely within a short time;  
(c) Tire is composed of rubber, carbon-black, sulfur and steel. Steel, which is not a combustible component, will be oxidized and will be transformed into one of the cement components.

Conventional cement-burning fuels are gas, oil and pulverized coal, which are blown into the kiln by burners, atomized with air, and burnt rapidly. Tire material, however, is elastic and to pulverize it minutely or to break it into the size necessary for pneumatic transport is extremely costly. Therefore, it was necessary to develop a method whereby it can be fed to the kiln in the largest possible sizes. By finding the maximum permissible size for complete burning in various types of kilns this technique was made economically attractive.

### 4.3 Process details

(a) The quantities that it is possible to utilize will vary according to the size of the kiln but for a cement kiln of typical capacity, the usable quantity will be 300 - 1000t/month (43 000 - 150 000 tires/month) per kiln. The flow diagram is shown in Fig. 5.

![Flow diagram of the waste tire burning system](image)

**Fig. 5.** Flow diagram of the waste tire burning system.

NC Saitama plant facilities are operated at the rate of 1.5t/hr (240 tires/hr).  
Tires are brought to the plant by truck and are stored. They come from various sources i.e. passenger car, truck, bus etc. They are sorted, according to the weight per tire, into 2 - 3 classes. Special care is taken to avoid changes in thermal load; this is achieved by feeding the tires according to classification.
In this plant, tires are not subjected to size reduction and are, instead, fed in their raw state by conveyor to the feeding mouth and into the kiln. Size reduction may, however, be necessary for some types of kiln. Tires are supplied to the kiln by the horizontal conveyor and vertical hook conveyor. The speeds of these conveyors are fixed. At the feeding mouth is an air-tight damper for preventing air leakage into the kiln.

(b) Energy saving effects. Measured lower (net) calorific values of oil and tire are as follows:

- Lower calorific value of oil \( H_l = 9200 \text{ kcal/l} \)
- Lower calorific value ordinary tire \( H_l = 8570 \text{ kcal/kg} \)
- Lower calorific steel tire, (steel content 25%) \( H_l = 7180 \text{ kcal/kg} \)

Theoretically, 1 kg of an average tire is equivalent to 0.86 l. of oil. However, in actual operation the calorific value of tire will not be utilized at 100% efficiency to replace the main fuels such as oil and coal but will be partially wasted in the form of an increased exhaust gas temperature. According to the performance in our plants effective utilization is 60 – 80%. Complete utilization of the calorific value remains a problem to be solved.

4.4 Quality of cement

Since tires contain no component deleterious to the quality of cement and, as proven from long experience in checking the quality of the product, there is no change in the quality of cement caused by feeding tires. Combustion residues of either tire and steel are not found in the finished cement.

4.5 Secondary pollution

As is clear from the above comparison of tires and oil, the sulfur and nitrogen content of tires is small; even in the actual operation \( \text{SO}_x \) and \( \text{NO}_x \) in the exhaust gas at the exit of the dust collector presented no problem. Commonly, there is concern that burning tires may cause black smoke and offensive odors but because they are burned completely at the high temperature of the kiln, these cannot be detected even by instrumental analysis.

5. COLLECTION OF WASTE TIRES

It can be said that the key to the success of recycling wastes as resources is in the establishment of collection routes. Waste tires come from two main sources. One is from tire shops and filling stations where worn car tires are exchanged and left abandoned; these supply about 70% of the total waste tires. The other is plants at which cars are scrapped, accounting for about 30%.

Collection routes of these waste tires are shown in Fig. 6. As can be seen, except for the waste tires originating from car-scrapping yards, the majority is from the course of the distribution routes of new tires.

Waste tires delivered to the cement plant are sorted into three classifications according to size — passenger car tire (7 kg), light truck tire (15 kg) and truck – bus tire (50 kg) — then stored.

6. ACTUAL UTILIZATION BY THE CEMENT INDUSTRY

Since November 1978, NC has actually practised this system in four of its plants. Scales and energy saving effects are given in Table 3.
Utilization of waste tires as a substitute fuel by the Japanese cement industry, NC included, as of February 1980 is practised in 23 plants of 12 companies, including those plants in the planning stage. As can be seen from Fig. 7, the practice is spreading throughout Japan.

7. COMPARISON WITH OTHER SYSTEMS

Economic comparison of this technique with other waste tire treatment and recycling systems is briefly made in Table 4.
Fig. 7. Utilization of waste tires by cement industry.

Table 4. Comparison of main waste tire treatment method

<table>
<thead>
<tr>
<th>Methods</th>
<th>Nihon cement process</th>
<th>Crushing (Burying)</th>
<th>Burning</th>
<th>Pyrolysis (Reclaim oil, carbon black)</th>
<th>Low temp. crushing (Reclaim powder rubber)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inside kiln burning</td>
<td></td>
<td>Buried under soil</td>
<td>Burnt as is or crushed, in boiler or incinerator</td>
<td>Crushed to about 5cm for pyrolysis</td>
<td>Crushed to about 5cm for cryogenic crushing by N₂ gas</td>
</tr>
<tr>
<td>Treating capacity (operating time)</td>
<td>100 - 1500t/mo (24 hr/day)</td>
<td>300 - 500t/mo (6 hr/day)</td>
<td>45 - 75t/mo (6 hr/day)</td>
<td>600t/mo (24 hr/day)</td>
<td>600t/mo (24 hr/day)</td>
</tr>
<tr>
<td>Treating cost</td>
<td>Low</td>
<td>High</td>
<td>High</td>
<td>Medium</td>
<td>High</td>
</tr>
<tr>
<td>Investment required</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>High</td>
<td>High</td>
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</tbody>
</table>

8. CONCLUSION

The problem of satisfactorily treating waste tires has been overcome by a combination of crushing followed by the burning and kiln operation of cement manufacture, not only from the viewpoint of environmental preservation but also for the development of a technique for utilizing wastes as a substitute fuel of high utility value. It is believed that this new approach is a significant step in the development of techniques for treating and recycling wastes.