

Recycling of Concrete

by T. NAWA

Hokkaido University, Graduated School of Engineering Faculty,
Division of Sustainable Engineering

The Need for Construction and Demolition Waste Minimization

- In 20 century we developed technologies based on an extensive “use-and-throw-away” philosophy, it has been recognized that we cannot continue this unrestricted use of natural resources and pollution of the world with waste.**
- In many countries, construction and demolition waste is considered as harmless, inert waste, which does not give rise to problem.**

The Need for Construction and Demolition Waste Minimization (cont.)

- **However, construction and demolition waste consists of huge amount of materials that are often deposited without any consideration, causing many problems and encouraging the illegal dumping of other kind of waste.**

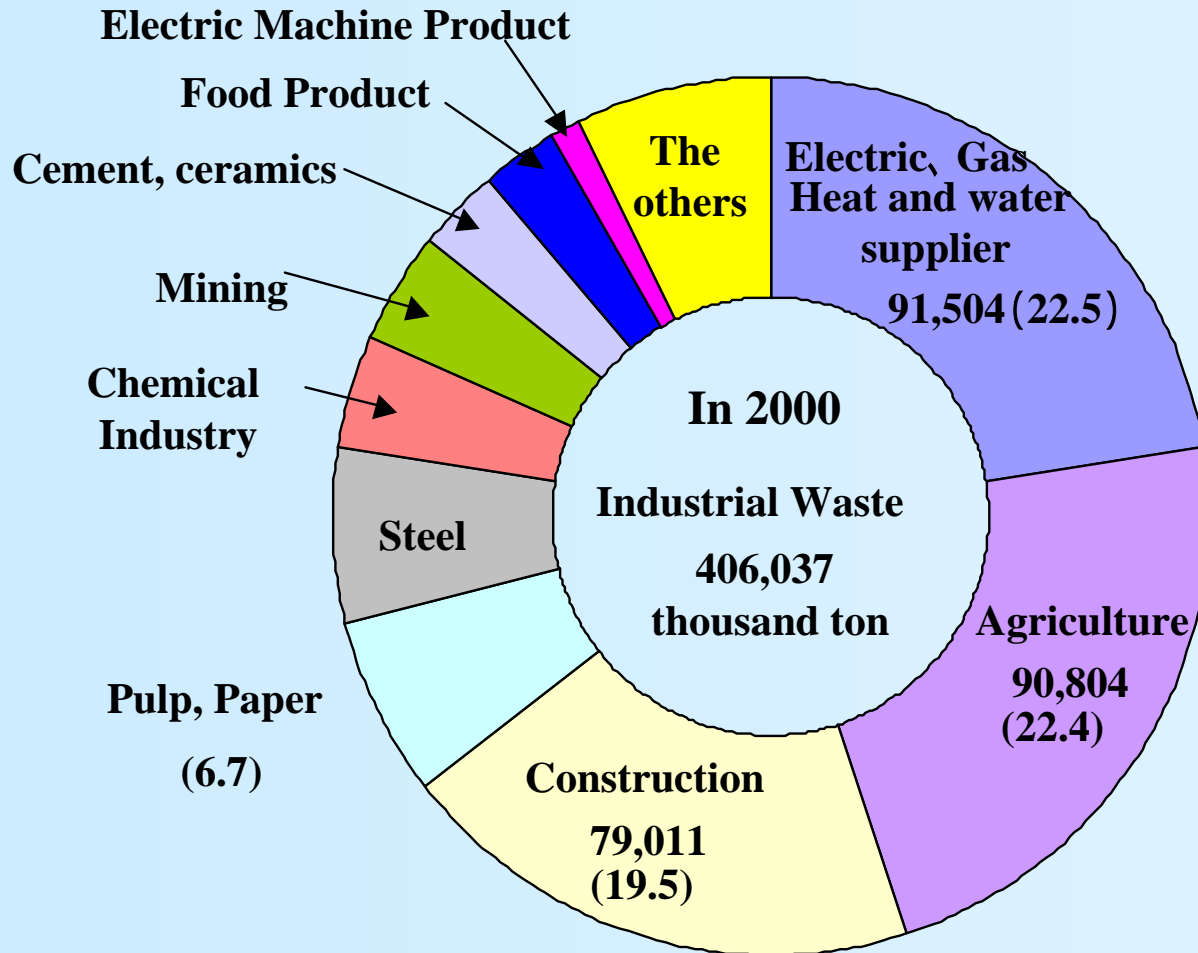
Construction and Demolition Waste in Japan

In Japan, the annual generation of construction and demolition waste is approximately 80 million tones.

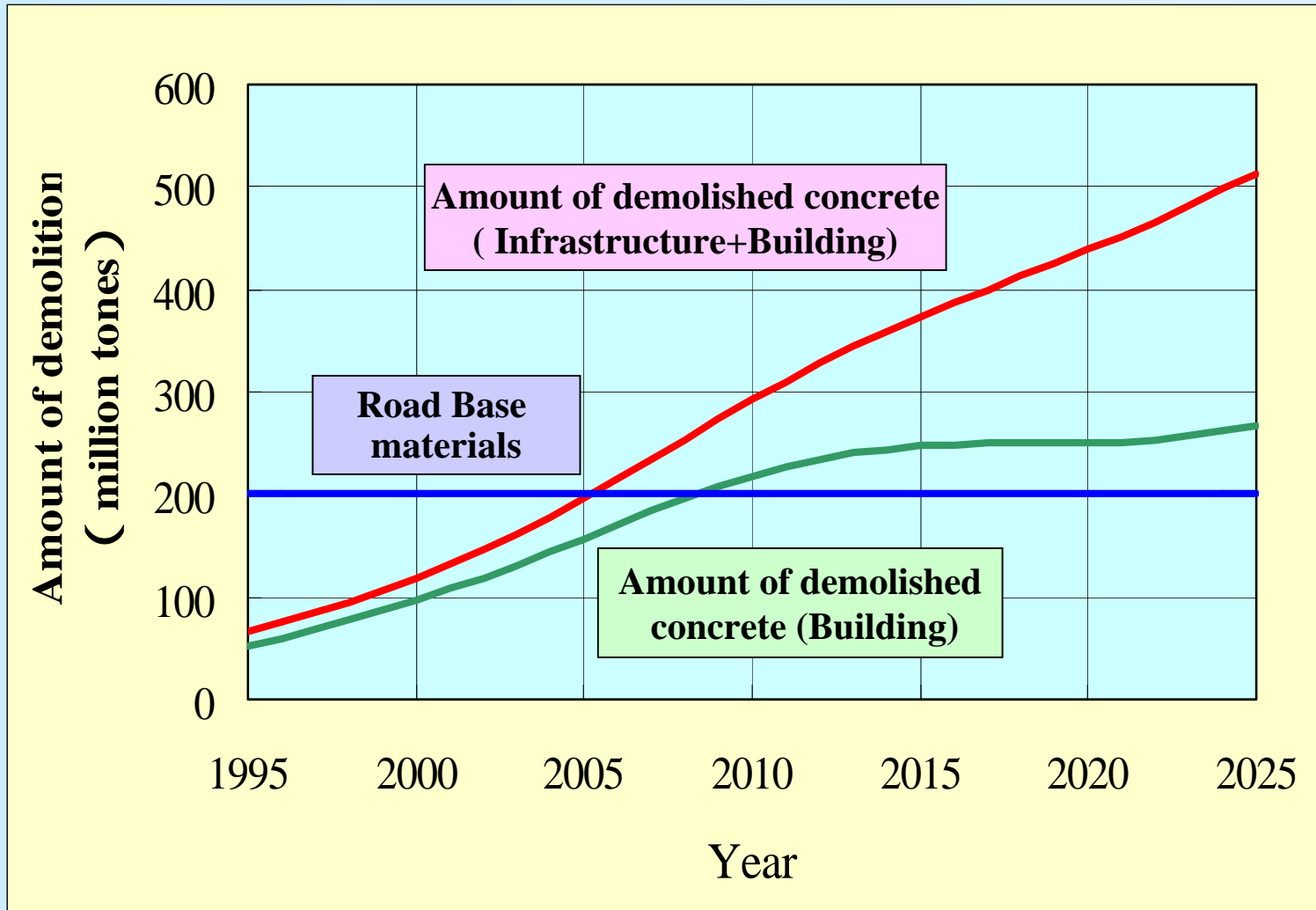
In the European Union (EU), the annual generation of construction and demolition waste is about 200-300 million tones.

In USA, the amount of construction and demolition waste is about 250-300 million tones per year.

Construction and Demolition Waste in Japan



The amount of demolished concrete in future



Sustainability and green concrete

- **Since Agenda 21, the Rio Declaration on Environment and Development, was launched in 1992, sustainable development has been one of the key issues of modern society.**
- **We should encourage the development and application of environmentally friendly, sustainable concrete materials, design and construction.**

Policies and Strategies

- **Construction & demolition waste must be considered as a specific individual type of waste associated with the building and construction industry.**
- **The management and handling of waste is carried out by the industry itself.**
- **However, the building and construction industry is relatively conservative, and we take a lot of time and need long-term policies and strategies to change in conventional procedures**

Policies and Strategies

- **Very severe barrier**

1. **Environmental politician in public office intend to prepare the policies and issue concerning waste recycling and reduction.**
2. **Building constructor is controlled by law.**

Integrate the interests of all parties, it is necessary that long-term polices and strategies should have been prepared and implemented.

Construction Recycle law

- **Law to promote effective recycle**
- **To refer specifically to concrete rubble, asphalt concrete rubble, and construction waste wood**

Before: the owner used to submit to the governor a demolition plan, indicating the type of structure and floor area of the building.

Construction Recycle law (cont.)

After formulation:

the owner should submit a “notification document ” for any planned generation of waste in the following cases:

- 1. Demolition of a building with a floor area greater than 80 m²**
- 2. New construction with a floor area than 500 m²**
- 3. Expansion, repair or remodeling of building costing more than 100 million yen.**
- 4. Public works projects exceeding a cost of 5 million yen.**

Each of the cases of 2,3,4 generates the same amount of waste as the case 1, which is estimated to be about 30 to 40 tons per house.

Construction Recycle law (cont.)

“Notification Document ”

- 1. Characteristics of the construction**
 - 1) the usage**
 - 2) number of stories**
 - 3) projected floor area**
- 2. General Contractor’s permit number**
- 3. Registration number of the demolition industry association**
- 4. Demolition method**
- 5. Separation waste material**
- 6. Amount of expected waste generation**
- 7. Cost of demolition work**
- 8. Name of the recycle plant**
- 9. Cost of waste recycling**

Progress in recycling and reuse of concrete as aggregate

- **Fortunately, some Japanese researcher had been investigated recycling of concrete since the early 1970s.**
- **In 1981, Japanese and European members of RILEM took the initiative to complete the first RILEM technical committee on the demolition and recycling of concrete, including several material research project in this field.**

Progress in recycling and reuse of concrete as aggregate (cont.)

In the early 1970 a large number of experimental investigations of the quality of recycled aggregate were performed by Kasai et al.

In 1977, the Japan Building Contractors Society (BCS) published the report, “Proposed Standard of Recycled Aggregate and Recycled Concrete and Commentary”

The first systematic proposal for recycled concrete in the world

Progress in recycling and reuse of concrete as aggregate (cont.)

**In 1986 the building Research Institute of the ministry of
Construction of Japan issued
the “Proposal of Quality Standard for Recycled Coarse
Aggregate” and
the “Proposed Standard for Recycled Coarse Aggregate
Concrete” :**

**the standard of recycled fine aggregate follows the
BCE standard of 1977.**

Quality Standard of Recycled Aggregate

	Recycled Coarse Aggregate			Recycled Fine Aggregate		
	1 st class	2 nd class		1 st class	2 nd class	
Water adsorption (%)	<3	<3	<5	<7	<5	<10
Loss of soundness	<12	<40*	<12	-	<10	-

* In this case, don't consider freezing and thawing deterioration

** For natural coarse aggregate, <3.0 % of water adsorption and <5.0% loss of soundness; for natural fine aggregate <3.5% of water adsorption

Design Strength of Recycled Concrete

In 1994, the ministry of Construction of Japan published “Tentative Quality Standard Proposal for Concrete”.

-- This formulated the design strength for recycled concrete in which recycled aggregate categories correspond to the quality standard provided in 1986.

Class of Recycled Concrete	Coarse Aggregate	Fine Aggregate	Design Strength (MPa)
I	1 st class	Ordinary aggregate	>20 (RC)
II	2 nd class	Ordinary aggregate or Recycled aggregate	>16 (Plain)
III	3rd class	Recycled aggregate	<16

Example of Structures Using Recycled Concrete (Civil Construction, not Buildings)

Class of Recycled Concrete	Usage	Coarse Aggregate	Fine Aggregate	Structures
I	RC & Plain C	1st class	Ordinary aggregate	Bridge substructure, Retaining wall, tunnel liner
II	Plain C	2nd class	Ordinary aggregate or Recycled aggregate	Concrete block, foundation of road attachment, side drain, gravity bridge basement, wave breaker, and so on
III	Concrete sub slab	3rd class	Recycled aggregate	Concrete sub slab, back fill concrete, non-structural member

Requests for the Successful Recycling of Demolished Concrete Rubble

- 1. Selective demolition must be made.**
- 2. Processing plants and depots for recycled materials must be established.**
- 3. Recycled products must be produced and marketed to compare with comparable new raw materials in terms of price and quality.**

Selective demolition

Selective demolition is defined as a process in which demolition takes place as ‘reverse construction’.

Different types and fractions of materials are removed from demolished structure and stored at the demolition sites, so that mixing of waste is avoided.

In the process serious attempts are made to separate , store and transport concrete rubble, but this is not always possible.

Processing plants and depots for recycled materials

It is necessary to establish processing plants and depots at strategic locations within a city in order to achieve the flexibility and economy necessary for employing recycled materials.

The right materials must be available in the right quantities, at right place, at the right price , and at the right time.

Economical benefit

The cost of selecting , sorting and processing of waste is usually higher than the value of comparable new raw materials.

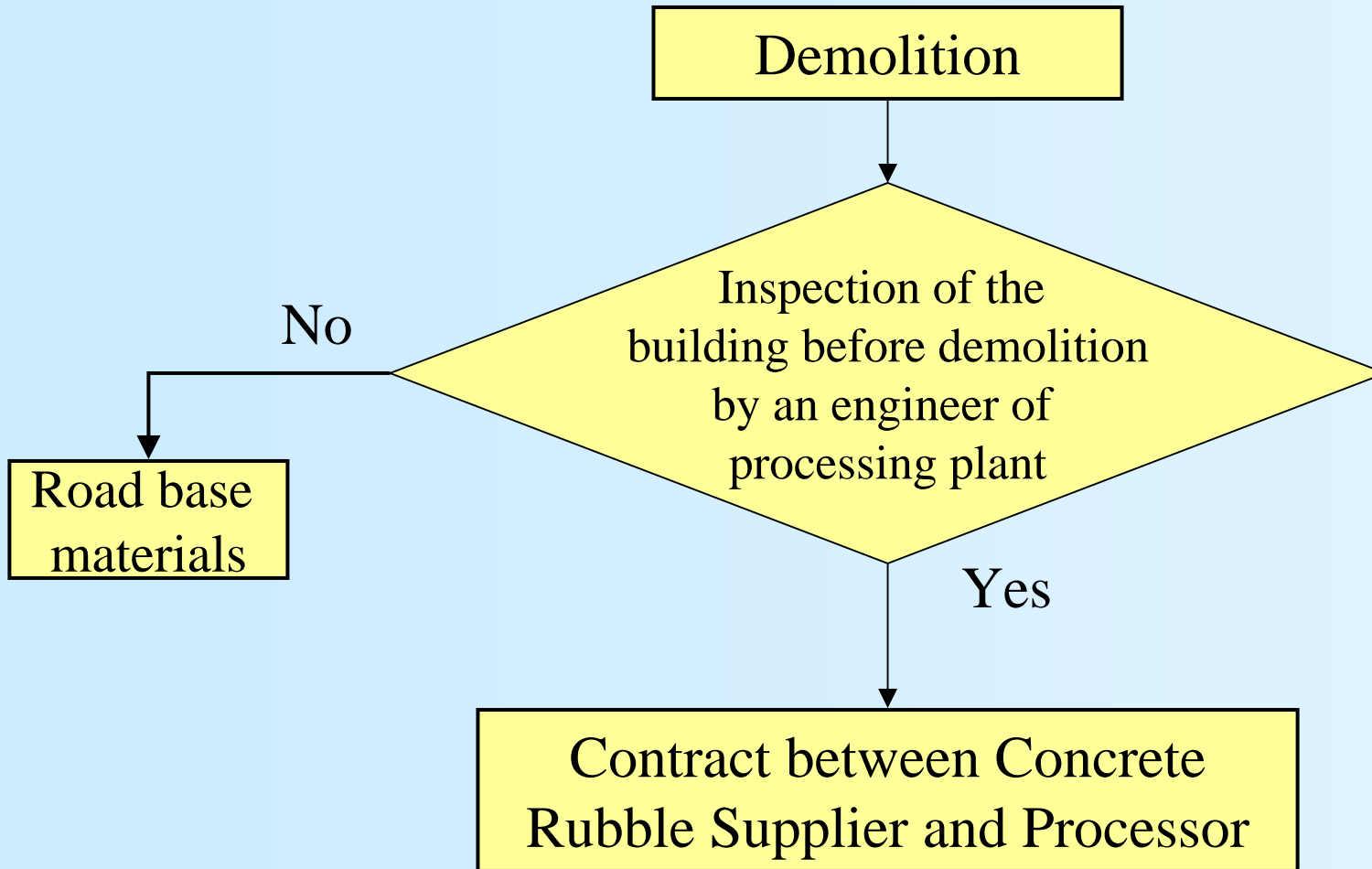
However, recycling of demolition waste can be made economical by imposing a fee on the waste, which is dumped at landfills.

As disposal fees gradually continue to increase, which is in the nature of all taxes and fees, so a level is soon reached where commercial recycling of demolished concrete rubble.

Quality of Recycled Concrete

It is requested that recycled materials either satisfy the requirements of already existing specifications for primary raw materials or the standards to be developed for recycling materials.

Outline of manufacturing process of recycled aggregate



Requirements for Original Concrete for Recycled Aggregate

1. Free from harmful components

- 1) soil**
- 2) mud**
- 3) asphalt**
- 4) ALC**

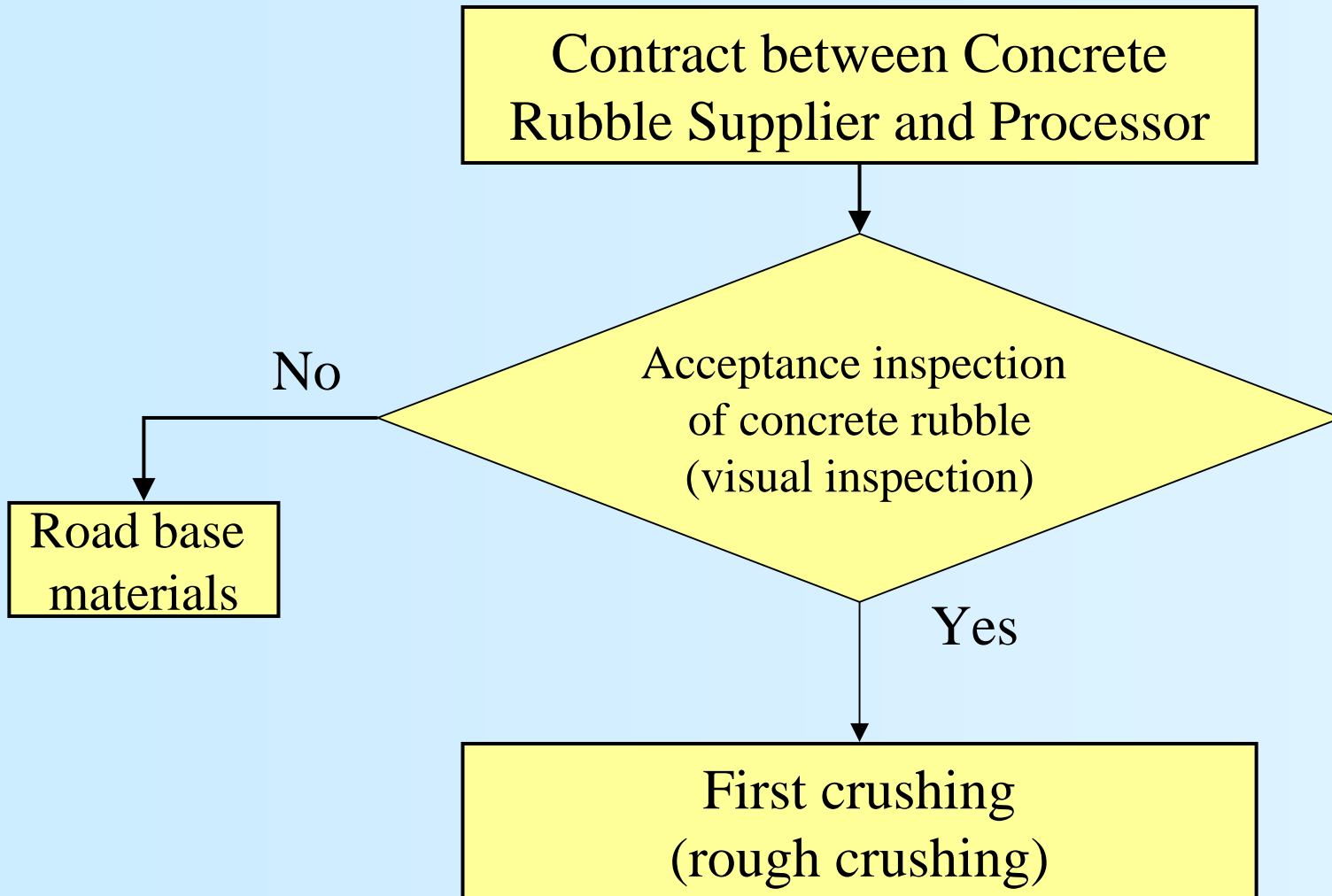
2. Free from harmful substance

- 1) chlorides**
- 2) alkali-reactive materials**

To guarantee this,

- inspect signs of corrosion of reinforcing bar due to chlorides,**
- Inspect cracks caused by alkali-aggregate reaction**

Outline of manufacturing process of recycled aggregate (cont.)



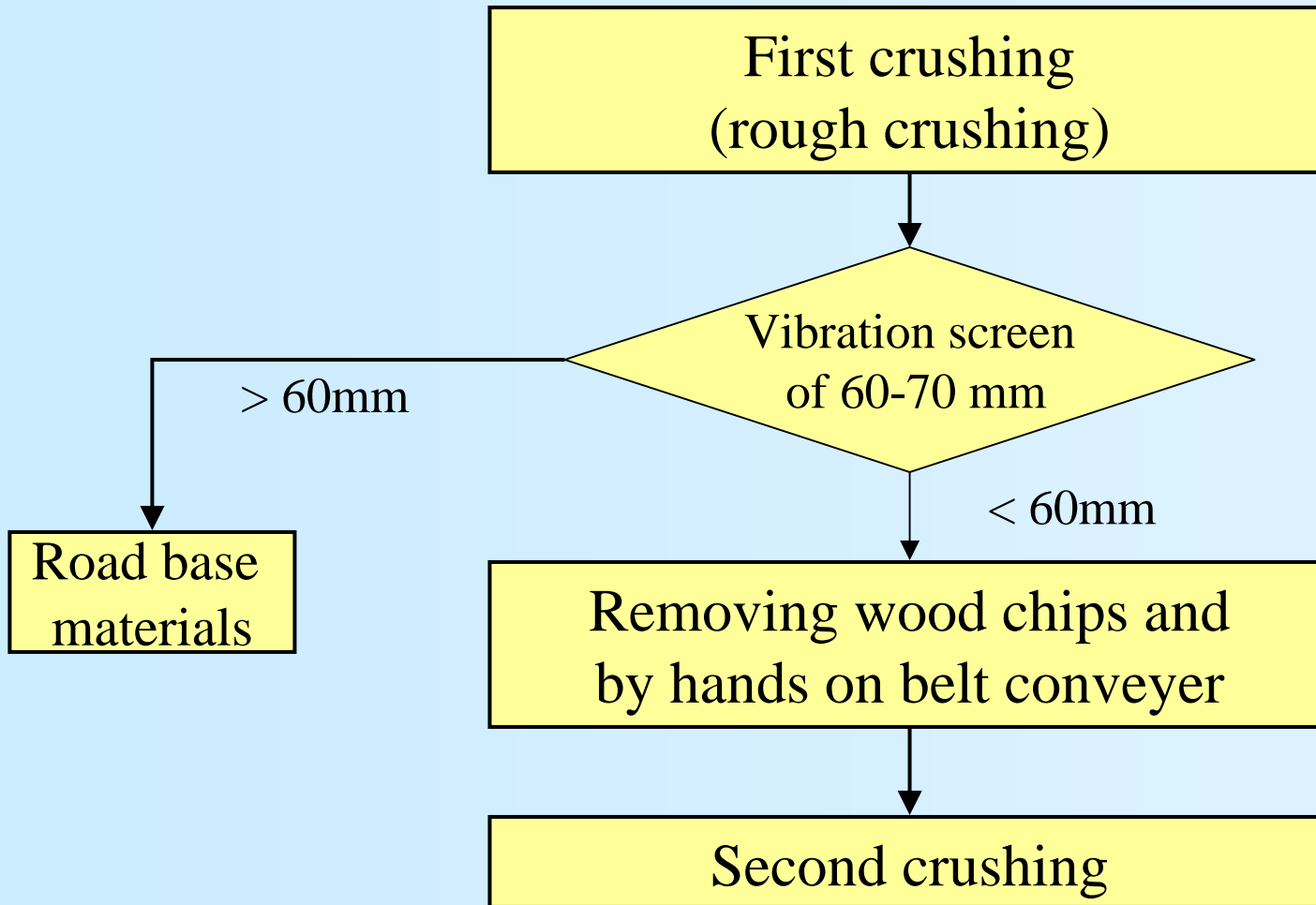
First Crushing of Concrete



First Crushing of Concrete



Outline of manufacturing process of recycled aggregate (cont.)



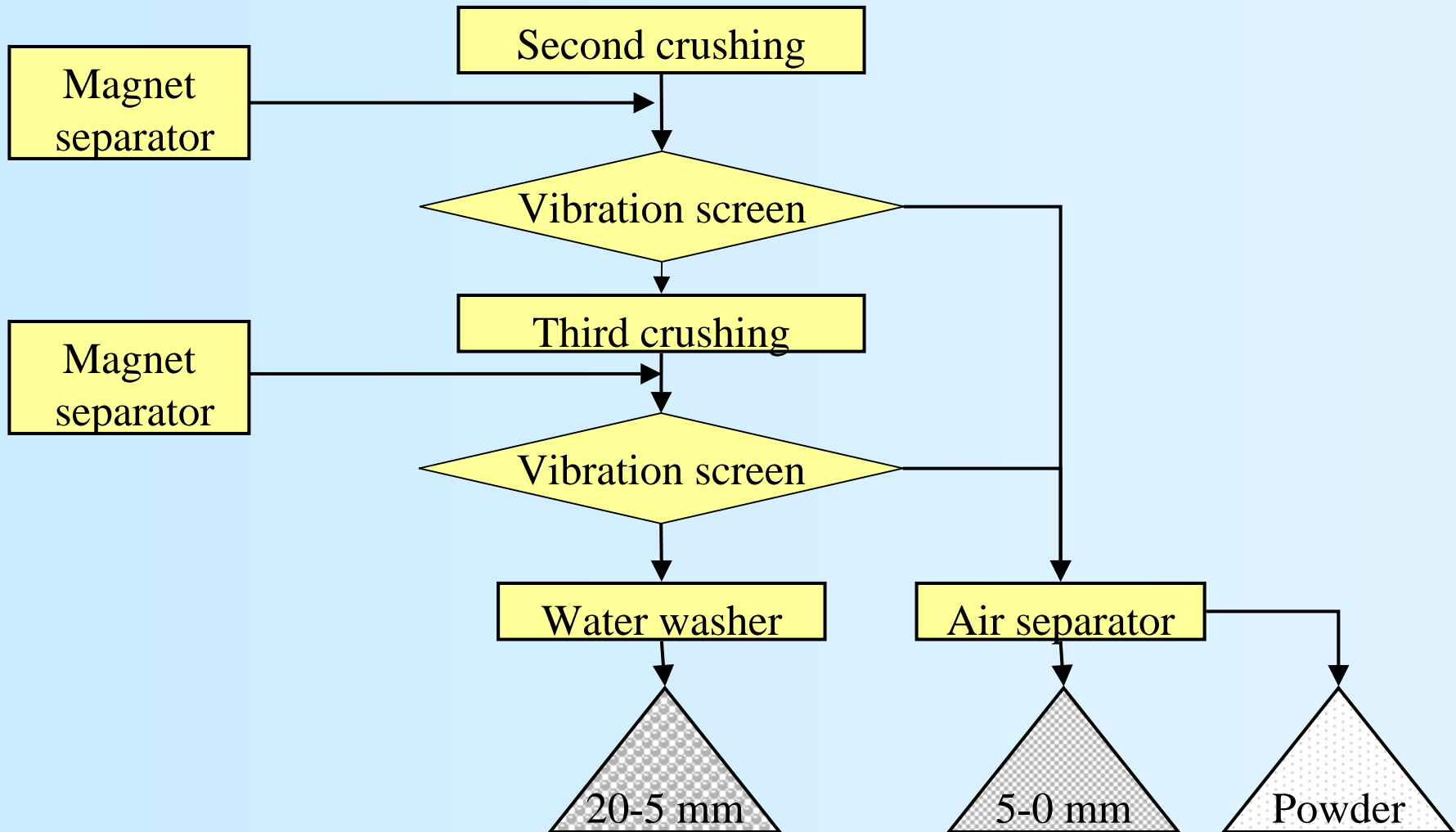
Second Crushing of Concrete



Second Crushing of Concrete



Outline of manufacturing process of recycled aggregate (cont.)



Recycled concrete aggregate(inspected at plant site)

Vibration screen



Recycled Coarse and Fine Aggregates



Production of Recycle Aggregate

- **Rubbing machine**

Mortal adhered to the original aggregate has acute angle, which should be remove during crushing.





Outside of screw grinding machine



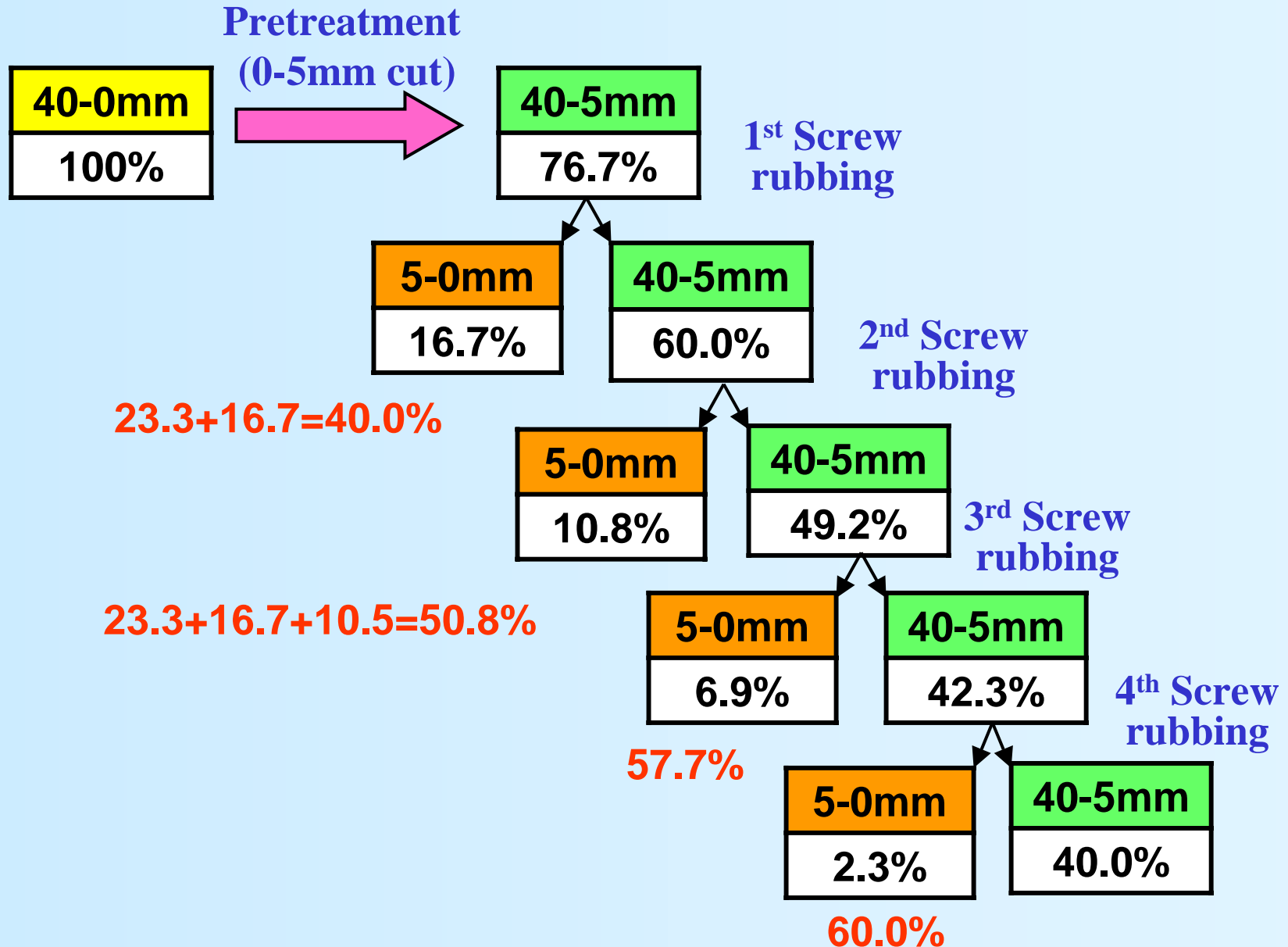
Inside of screw grinding machine

Production data for Recycled coarse aggregate

Term	Data
Manufacturing capacity	5 – 10 tons/hour
percentage of admitted products	50 - 55%
Workers for manufacturing and quality control	4 –5 persons /day
Date for construction and dismantling of plant	About 2 days for each process
Power consumption	18 kWh/ton (\ 450yens/ton)
Level of loudness	50 – 60 dB
Level of vibration	50 – 60 dB
Concentration of dust	10 – 20 mg/m³

Original aggregate: River gravel, 3times grinding

Percentage of admitted products



Problems with Quality of Recycled Aggregate

1 . Lower strength

2 . Larger shrinkage

Recycled concrete contains the mortar and fine particles.

3. Low freezing–thawing resistance

The freezing-thawing resistance of concrete made with recycled aggregate from non-air-entrained concrete was low. On the other hand, if the original concrete was air-entrained, the frost resistance of recycled concrete were sufficiently good.

Problems with Quality of Recycled Aggregate

**With 100% recycled coarse and fine aggregate, the strength
And durability of concrete are decrease significantly.**

4. Mixed use of recycled and regular aggregate

Substituting regular aggregate for recycled aggregate

**30% replacement : almost the same strength as that of concrete
with regular alone.**

**In a particular application, there exist suitable combinations of
recycled and regular aggregate**

Ex.1 100% recycled coarse aggregate with 100% regular sand

**Ex.2 50% replacement of recycled and regular coarse and fine
aggregate**

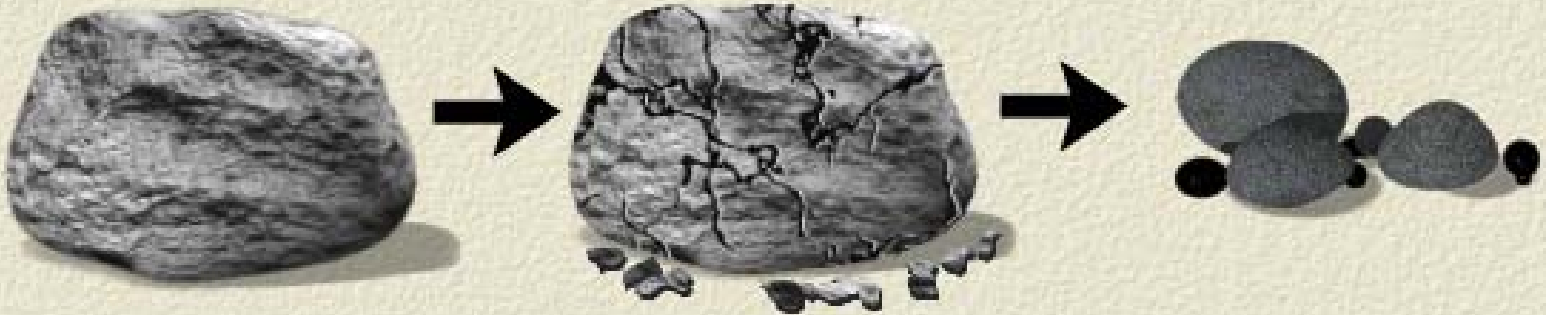
Improvement of Recycled Aggregate

- **Heating and grinding Method**

Demolished concrete is heated in furnace tower up to 300°C for 40 to 60 min, which produces fine crack between the cement paste and the aggregate.

Then heated concrete rubble is crushed by a tube mill to abrade the mortar adhered to the original aggregate, and this way we obtained good recycle coarse aggregate and fine aggregate.

Mechanism to Produce High-quality Recycled Aggregate



Heat treatment

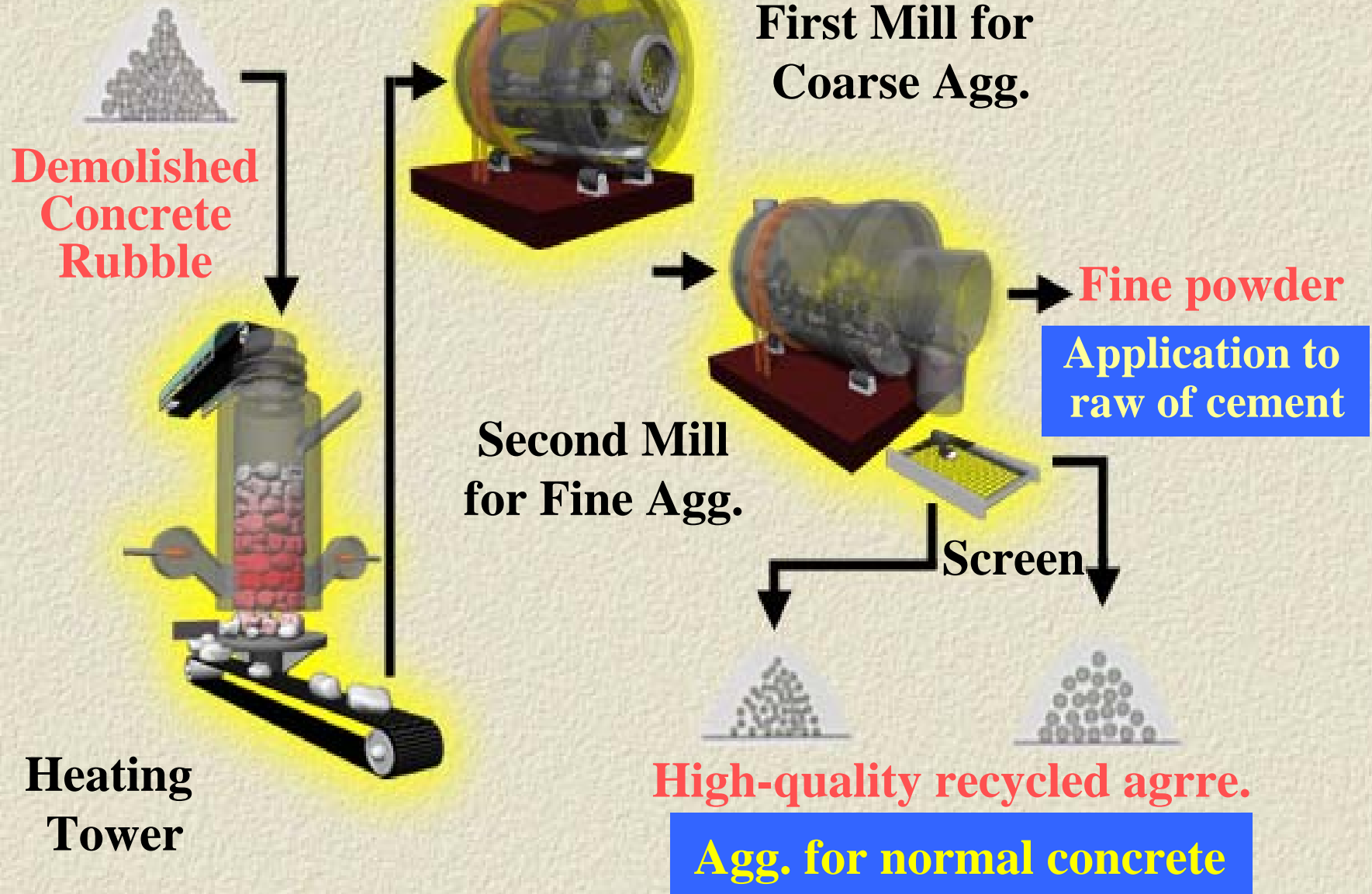
Rubbing treatment



Concrete Rubble

**Weakening Paste
due to Heating**

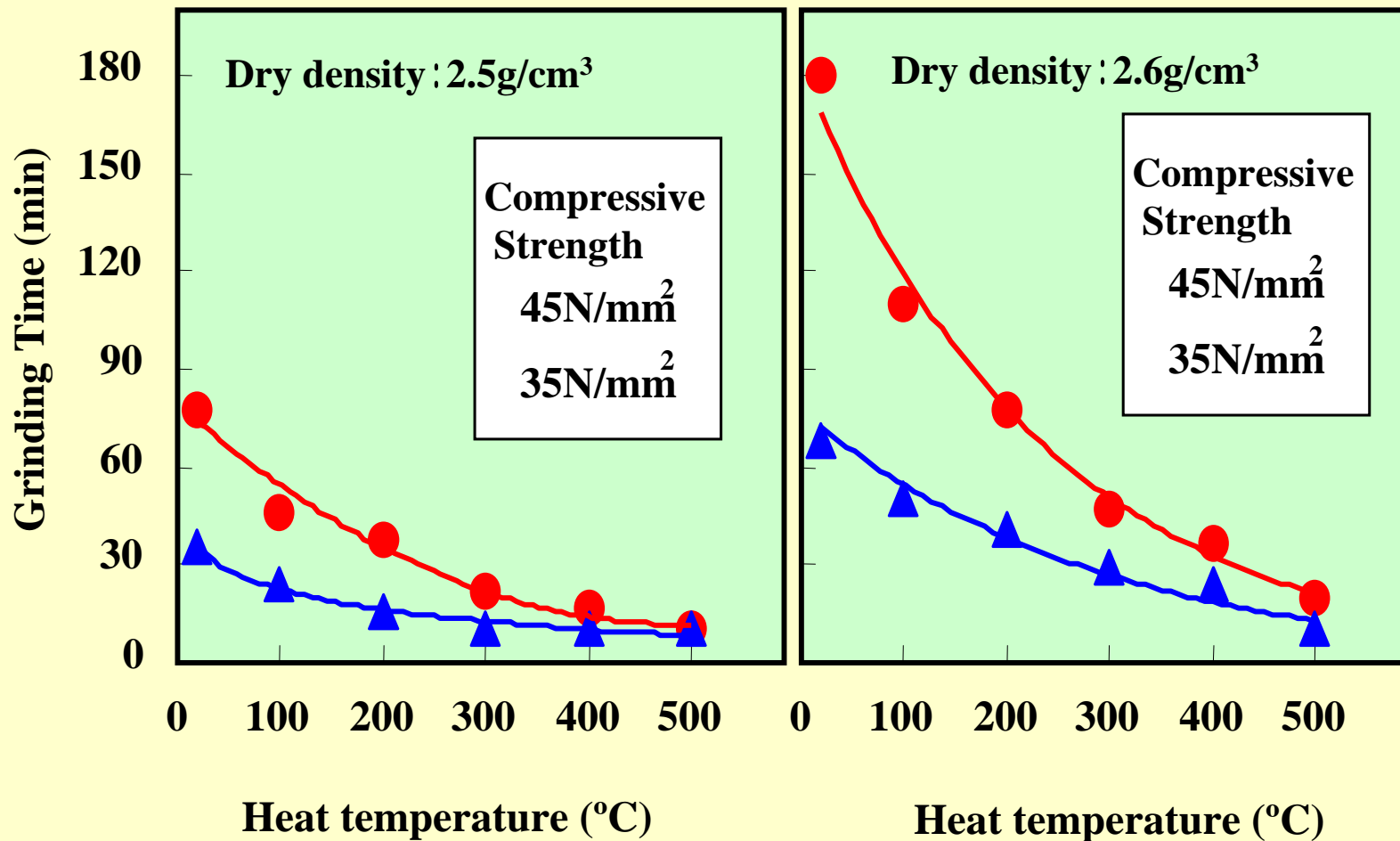
**Selective remove
of Paste**



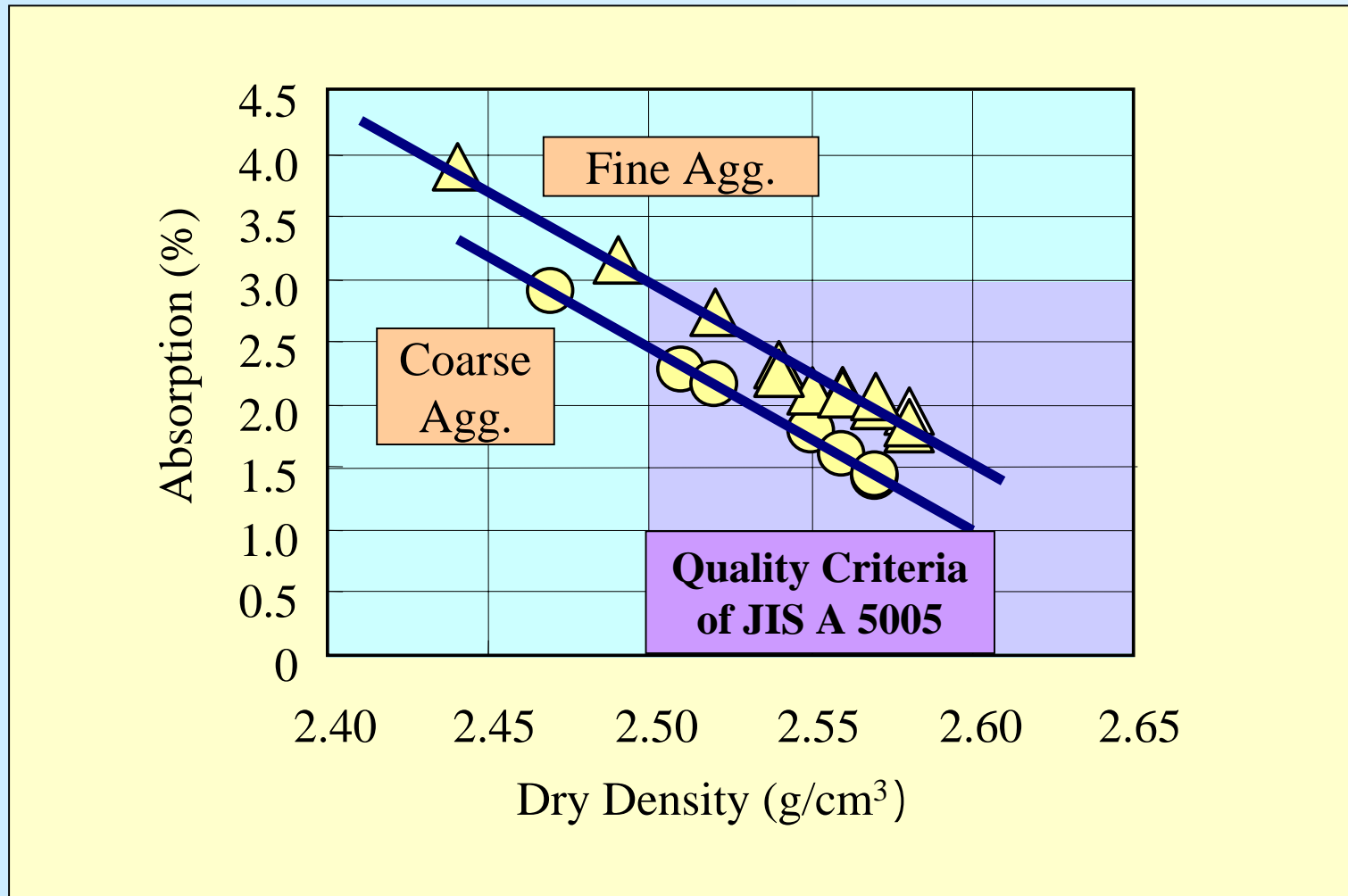
Outline of Heating and Abrading plant with 3 t/h capacity



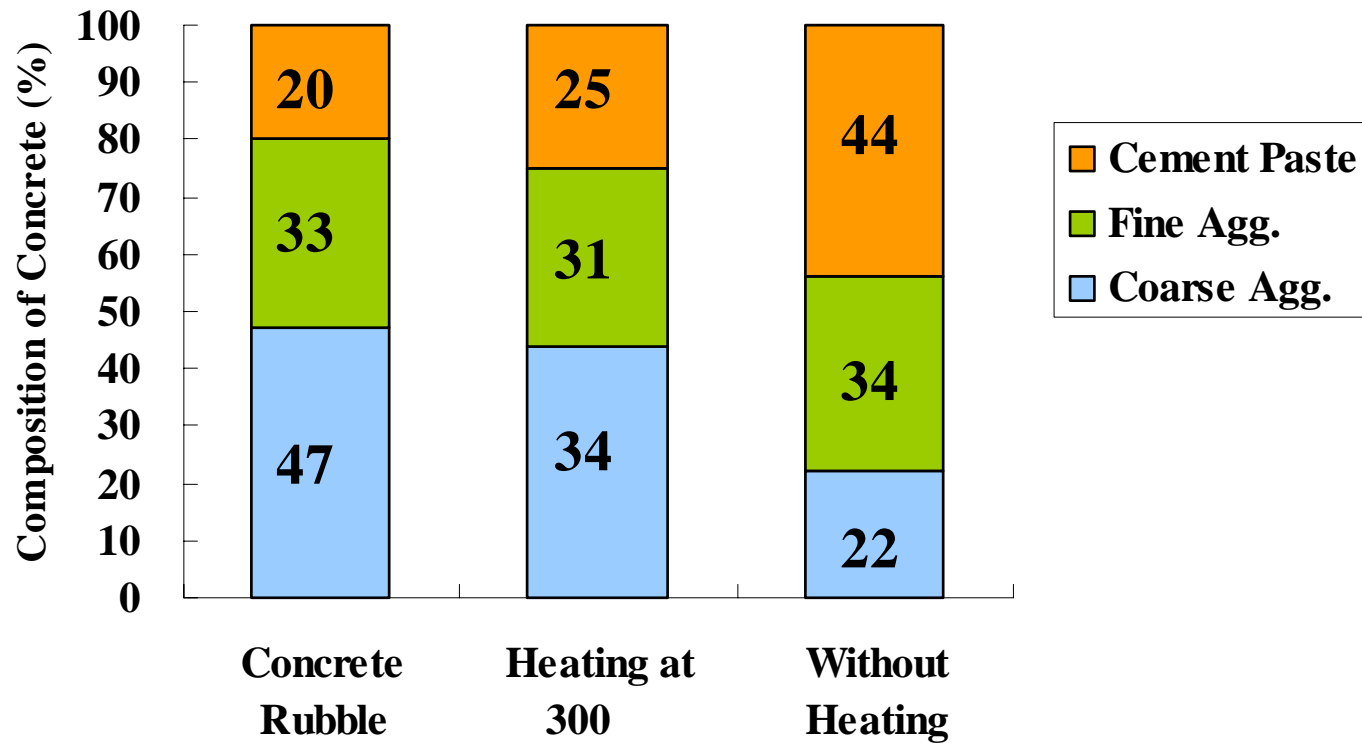
Effect of Heat Temperature on Grinding Time Satisfied the Requirement of Dry Density of Aggregate



Relation between Dry Density and Absorption of Aggregate Manufactured by Heating and Rubbing Methods



Composition of Original Concrete and Recycled Concrete

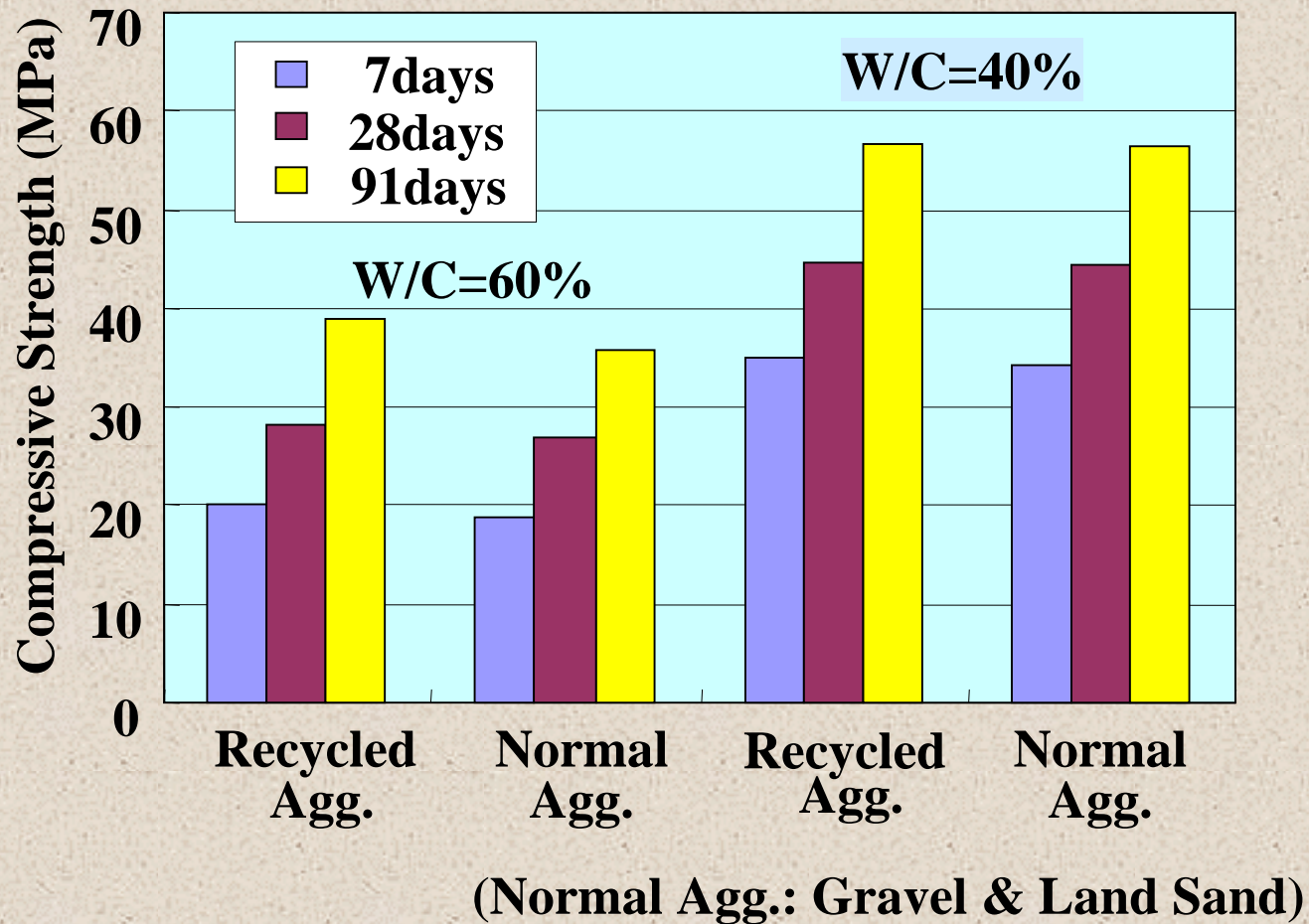


Properties of Recycled Concrete

Mix Proportion of Recycled Concrete

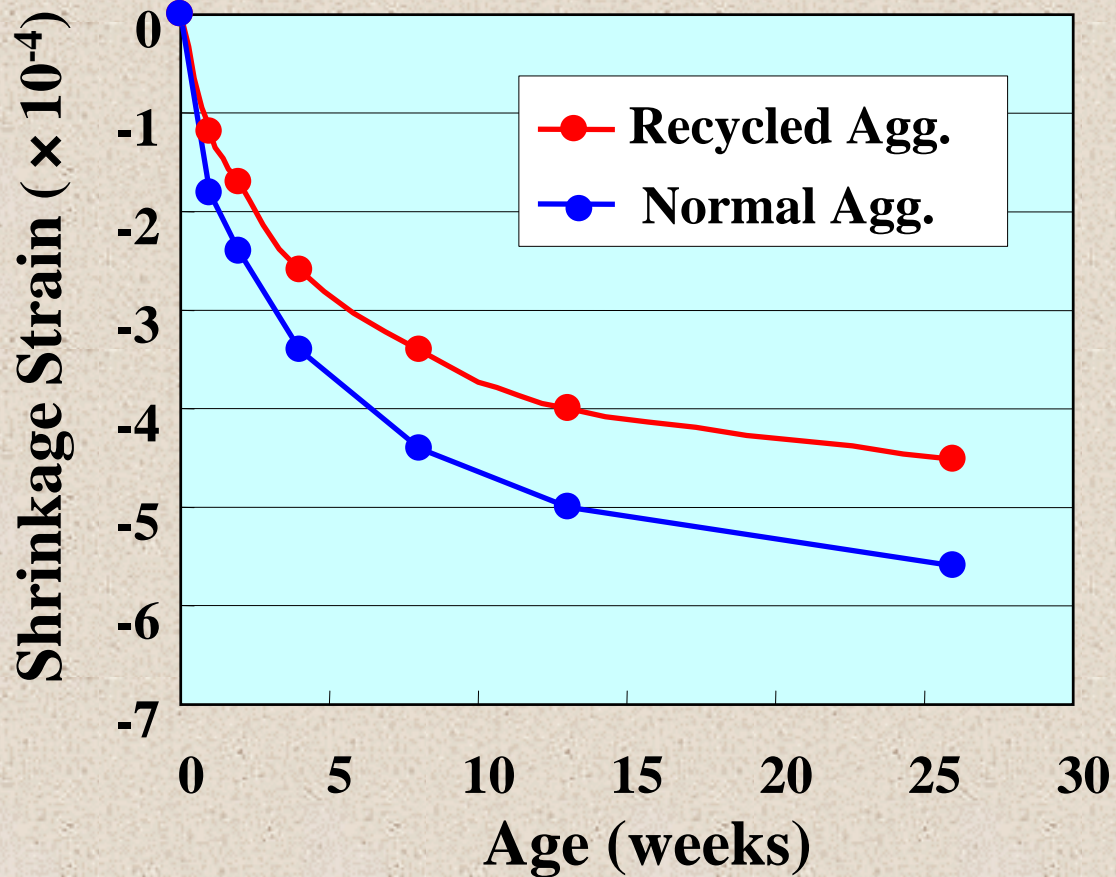
Kind of	W/C (%)	s/a (%)	Unit Quantity (kg/m ³)				
			Water	Cement	FA	Fine Agg.	Coarse Agg.
Recycled Concrete	45.6	46.4	152	266	67	832	963
Normal Concrete	48.3	47.3	170	282	70	821	960

Properties of Recycled Concrete



Properties of Recycled Concrete

Drying Shrinkage



Further Problems with Recycling of Concrete

1 . Salt within recycled aggregate

Recycled concrete contains the mortar and fine particles.

2 . Alkali-aggregate reaction of recycled aggregate

The freezing-thawing resistance of concrete made with recycled aggregate from non-air-entrained concrete was low. On the other hand, if the original concrete was air-entrained, the frost resistance of recycled concrete were sufficiently good.

Education

The most important measures to overcome the barrier toward recycling of concrete, is educations.

It is necessary that the message and understanding of recycling be discussed at technical universities.

Thank You

