Third International Conference on Sustainable Construction Materials and Technologies http://www.claisse.info/Proceedings.htm

# The Packing System Analysis required to Evaluate $CO_2$ Emissions During Whole Building Materials Transportion

M.Tamura[1] and Y.Nachi[2]

[1]*School of Architecture, Kogakuin University, Tokyo, Japan*
[2]*Shimizu Corporation, Tokyo,Japan*
*1-24-2 Nishi-shinjyuku,Hinjyuku-ku, Tokyo, JAPAN, masaki-t@cc.kogakuin.ac.jp*

## ABSTRACT

The whole building materials are large varieties and have been carried by many kinds of transport methods. Therefore, the environmental impact on the total amount of $CO_2$ emissions due to the transportation of whole building materials, such as building interior/exterior products from outside raw material/products plants to construction sites would be necessary to evaluate in detail. This study intends to analyze the requirements to the packing pattern of cargo during transportation and the systems including the total transport distances and number of times to evaluate $CO_2$ emmissions various building materials to be considered the related last studies of us. The type-of-packing pattern considering the process level could be classified into "A type" and "B type",which is decided the value of bulk weight per unit volume of material/product and the value of limited capacity of weight of career.When assessing the environmental conditions of $CO_2$ emmitions related to these transportations for building materials, it is necessary to improve the estimation method in view of these type-of-packing patterns and the process levels.

**Keywords.** Environmental load, Building materials, Packing pattern, Bulk weight per unit volume, Limited capacity of weight

## INTRODUCTION

Building materials such as structural / finishing materials used in the urbanaized areas in Japan have been recently transported by mainly trucks over a long distance with a long transportation time. Therefore, in addition the previous issues of safety management for drivers and trafiic road, the environmental impact from the total amount of CO2 emissions due to transport of these materials from outside raw material / products plants to construction sites will become an important issue.

This study intends to analyze the packing pattern of cargo and the systems including the total transport distances and number of times to mitigate environmental impacts on transportation of various building materials based on the field survey in building construction process.

The procedure of study was as follows, to select the typical structure buildings(Steel structure, Reinforced concrete structure) constructed in urbanized area, to investigate the packing pattern of cargo during transportation from raw materials / products plants to the

construction site of building, and finally to analyze the two kinds of packaging methods by limiting weight capacities(A type) / volumetric capacities(B type) for their transportation conditions. It would be useful to reduce the CO2 emissions due to energy consumption during transportation.

## THE LOGISTICS ISSUE OF BUILDING CONSTRUCTION

The various attempts have been made in Japan from the aspect of use of earthquake disaster debris, recycled aggregate and industrial byproducts in concrete. On the other hand, new technology frameworks related to the production of environment-conscious concrete structures have recently been proposed, while the ISO specifications dealing with the sustainability of buildings are aimed at formulating assessment indices based not only on the environment but also on its balance with society and the economy.

In these circumstances, the environmental loads by $CO_2$ emission from transportation have been causing concern and the environmental loads during long-distance transportation of materials such as aggregate and other building materials should therefore be properly evaluated. So, it would be very important to conduct the case studies of evaluating the packing pattern of cargo during transportation in the actual buildings cast in Tokyo area.

## THE OBJECT OF RESEARCH

Table 1 shows framework of the study. The object of the research 1 was to classify the kinds and properties of the applied building materials in actual building in Tokyo, and these investigations regarding the major type of structure (structural steel frame, reinforced concrete foundations and etc.) and the whole the kinds and properties of exterior, interior and finishing materials were confirmed.

The object of the research 2 were to classify the means of transportation of each construction materials by questionnaire investigation to a special constructors (packing pattern, kinds of careers, transportation routes, times of transportation and etc.) were conducted.

The objectives of the research 3 and 4 was to analysis more in detail the properties of means of transportation of each construction materials by questionnaire investigation to a special constructors (volumetric size and weight of packing of careers, relationship between the each of building materials, packing conditions of career and etc.) and finally the relationship between the process levels of producing building materials and the unit weight of materials/products could be explained the each A and B indicators. A type was set as ( $\alpha \geqq \beta$ Weight limited) and B type was set as ( $\beta > \alpha$ Volume limited), and $\alpha$ is the value of bulk weight per unit volume of material/product and $\beta$ is the value of limited capacity of weight of career.

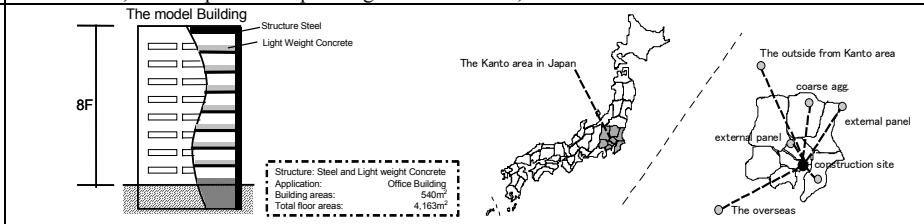
Table 2 shows the related properties of the investigated building. The composition of the building was steel-frame structure, the first basement level and eight stories above ground, and total floor area 4,163$m^2$. The construction site of the building was Koto area in the central of Tokyo and planned to use as office building. The building materials were composed such as steel-frame, roof asphalt waterproofing control concrete, aluminum curtain wall, steel plate sandwich panel and etc.

**Table 1. Framework of the study**

| items | Contents |
|---|---|
| Objectives | The steel-frame and reinforced concrete foundation buildings（built in Tokyo metropolitan area in 2009） |
| Research 1 | Classification of kinds of the applied building materials for buildings settled in Tokyo area.<br>-The major types and properties of structure: structural steel frame, reinforced concrete foundations and etc.<br>-The whole types and properties of exterior, interior and finishing materials: the 5 kinds of structural materials, the 31 kinds of finishing materials |
| Research 2 | The means of transport of each construction materials by hearing investigation to a special constructor.<br>-kinds of careers , -transportation routes, -times of transportation |
| Research 3 | The conditions of transport of each construction materials by hearing investigation to a special constructor.<br>-the volumetric size and weight of packing of careers<br>-the relationship between the each of building materials and the conditions of career |
| Research 4 | The relationship between process levels and weight of material/product with each trucks by A and B indicators.<br>-A type( $\alpha \geqq \beta$ Weight limited) -B type( $\beta > \alpha$ Volume limited)<br>$\alpha$ ：bulk weight per unit volume of material/product, $\beta$ ：Limited capacity of weight of career. |

Note）Transport career on the land（2，4，10，15，28ton truck）

**Table 2. Characteristics and related properties of the investigated building**

| Items | Contents |
|---|---|
| Composition | Steel-frame structure, The first basement level and eight stories above ground （total floor area 4,163m$^2$） |
| Site and use | Site: Koto area in the centre of Tokyo, Use of building: Office building |
| Materials | Steel-frame , Roof Asphalt waterproofing control concrete, Aluminum curtain wall etc. |
| Model building and mapping |  |

## THE TRANSPORTAION OF BUILDING MATERIALS AND PRODUCTS

Table 3 shows the means of transport and the in-vehicle weight characteristic for investigated building, and table 4 shows the characteristics of type-of-packing pattern for building materials. With the results of research 1, the major building materials which were applied to the construction was extracted. The survey result of materials transportation states (transport routes, type of packing and freight etc.) and the properties of building materials (form, weight and capacity etc.) have been related to the means of transport of building materials. The ratio of using 4ton track for transportation of a construction material gets about 60 percent of all cases, and regarding the finishing materials and the fittings, the about 70 percent or more was transported by 4ton track. Since the construction site was located in the center of Tokyo, the construction site is too small and the place which keeps building materials or products were not able to be secured in the construction site.

The type-of-packing patterns for building materials were consisted of ”Encapsulated type”, “Level stacked type”, “Unit Stand type” and “Level placed type”, and the type-of-packing patterns would be thought to deep relate the process level of these building materials or products, these process levels for them were set as “Raw Material level”, “Intended material level”, “Building products level” and “Member level”.

"Encapsulated type" has conveyed the thing of the state of "Raw Material level" which the state of materials was liquefied and powdered thing. The liquefied and powdered thing is applied such as cement, admixture materials and ready-mixed concrete, etc. are applied.

"Level stacked type" has conveyed the thing of the state of "Intended material level" which the state of building materials of cross-sectional size, thickness, etc. were settled beforehand. These materials are conveyed From a materials manufacturing plant to a product molding plant by a palette. These were corresponded as examples for reinforcement, molding, gypsum board and ALC panel etc.

"Unit Stand type" has conveyed the thing of the state of "Building products level" which the state of these building materials were defined the form and a size, and put on an stand for the exclusive use, and are conveyed to the construction site from building product factory. These were corresponded as examples for glass, heat insulation sandwich panel and system ceiling etc.

"Level placed type" has conveyed the thing of the state of "Member level" which the state of the building products were already assembled and packing care, and these were placed and conveyed by the level platform. These were corresponded as examples for structure steel member, aluminum curtain wall and steel door etc.
In additions, the ratio of both packing patterns of "Level stacked type" and "Unit Stand type" get about 80 percent of all cases.

**Table 3. The means of transport and the in-vehicle weight characteristic for the objectives**

| Items | Contents | In-vehicle quantity | | | |
|---|---|---|---|---|---|
| | | 4ton | 10ton | 15ton | 28ton |
| Flat truck | There is no cover and it is a state of an open air. | ○ | ○ | ○ | – |
| Flat truck with jolo | There are the cloth and the steel covers for water and soil prevention. | ○ | ○ | – | – |
| Flat truck with small crane | The small crane which becomes handling of freight is installed in the loading platform. | ○ | ○ | – | – |
| Trailer | It does not have a engine in the vehicles itself, but has a platform for being carried chiefly. | – | – | – | ○ |
| Agitator | It conveys agitating a ready mixed concrete. | – | ○ | – | – |
| Container ship | The standard container for steel cargo (45 feet (about 13.7 m), 40 feet (about 12 m), and 20 feet (about 6 m) is conveyed. | – | – | – | – |

**Table 4. The characteristics of type-of-packing pattern for building materials**

| type | Encapsulated type | Level stacked type | Unit Stand type | Level placed type |
|---|---|---|---|---|
| Contents | ・liquid /powdered material<br>・conveyed in encapsulated condition | ・hardened and then form material<br>・conveyed in level stacked condition | ・building fittings/products<br>・conveyed in unit stand condition | ・large-sized uniformed products<br>・conveyed in level placed condition |
| system and image | [Side] [Back] In-vehicle quantity ・10ton [Example]  | [Side] [Back] In-vehicle quantity ・4,10,15ton [Example]  | [Side] [Back] In-vehicle quantity ・4,10ton [Example]  | [Side] [Back] In-vehicle quantity ・4,10,28ton [Example]  |
| Process level | Raw Material level | Intended material level | Building products level | Member level |

## THE CHARACTORISTICS OF TYPE-OF-PACKING FOR BUILDING MATERIALS

Figure 2. shows the type of capacity indicator A and B for building materials, Table 5 shows the characteristics of type-of-packing pattern for building materials, and Table 6 shows the judgements on A-type and B-type from the transportation states. As the above the results, these could be confirmed deeply relationships between these packing-patterns (Encapsulated type, Level stacked type, Unit Stand type, Level placed type) with these process levels (Raw Material level, Intended material level, Building products level, Member level). These relationship can be calculated from the bulk density of a cargo of vehicles, and the total freight set as vehicles beforehand. It can classify into "A type(weight type)" it is decided that a loading limit will be, and "B type(volume type)" it is decided that a volumetric capacity limit will be according to the combined of the building materials put on a vehicles.

On the basis of these results based on questionnaires surveys and analysis, the relation of kinds of building materials or products, packing patterns, and these process levels is taken into consideration, and is expectable to patternize the mode of transportation from a materials factory to the actual construction site.As a result, the fundamental information which could be calculated the amount of environmental impacts at the time of the transportation of each construction material based on the ton-kilometer method and etc. could be evaluated more clearly in the near future.

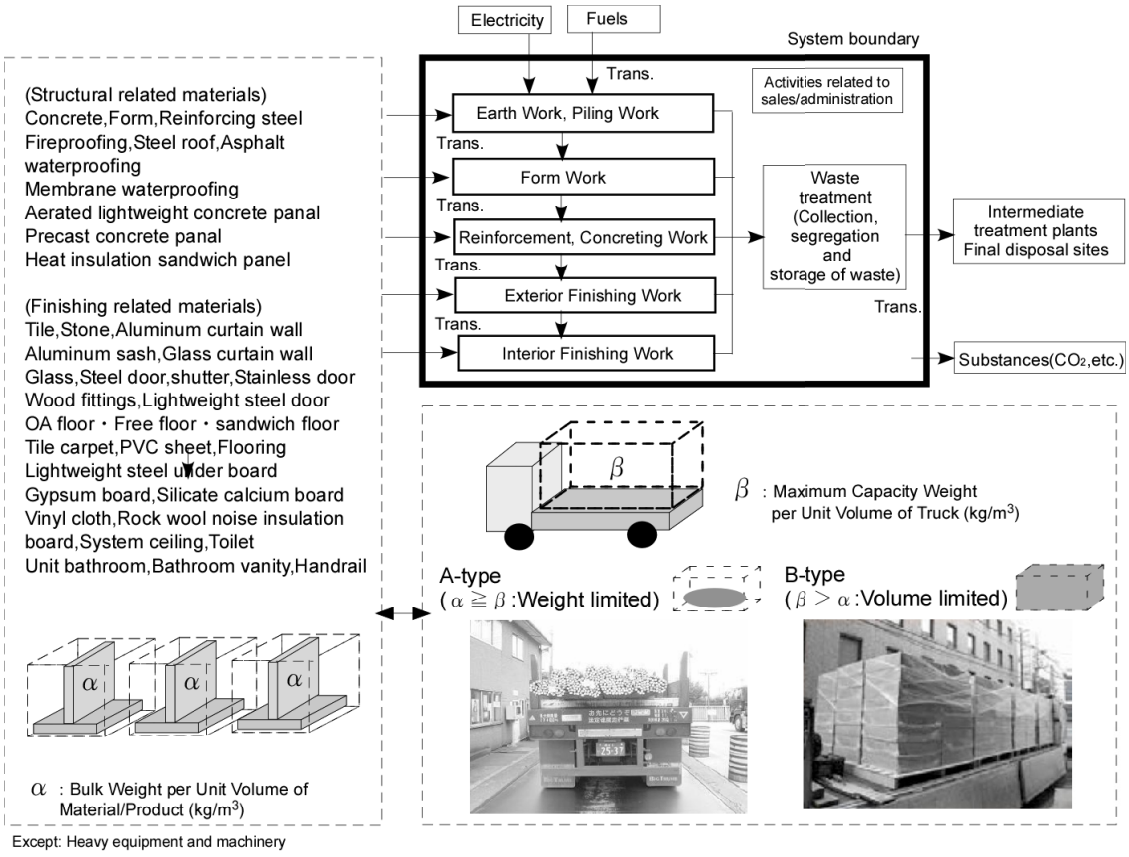


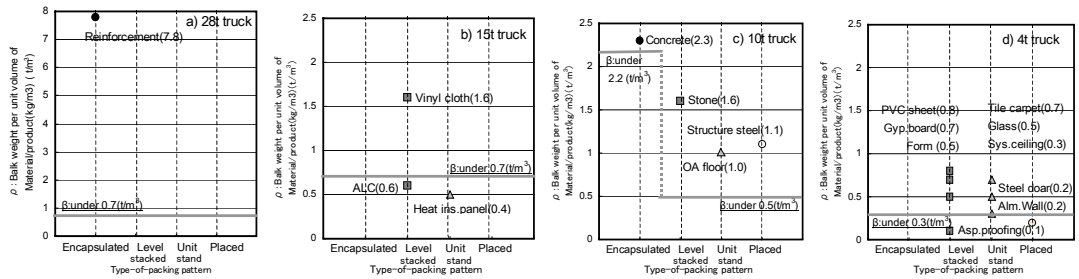

**Figure 2. The system of type A and B for building materials.**

## Table 5. The survey result of materials transportation states

| Classifications | | | Means of transport. | Packing | Vol/Weight | Bulk weight per unit weight(t/m3) |
|---|---|---|---|---|---|---|
| structural body | reinforced concrete | Concrete | 4.5m$^3$/unit | Agitator（10t） | Encapsulated | 2.3 |
| | | Form | — | Flat truck with small crane（4t） | Level placed | 0.5 |
| | | Reinforcing | 25.41 t / unit | Trailer（28t） | Level placed | 7.8 |
| | Structural steel | Steel | 7 t / unit | Flat truck（10t） | Level placed | 1.1 |
| | | Fireproofing | 10,920m$^2$/ unit | Flat truck（10t） | Level stacked | --- |
| finishing materials | Roof | Asphalt waterproofing | 125m$^2$/ unit | Flat truck（4t） | Unit Stand | 0.1 |
| | Outer wall | Aerated lightweight concrete panal | 200m$^2$/ unit | Flat truck（15t） | Level stacked | --- |
| | | Heat insulation sandwich panel | 260m$^2$/ unit | Flat truck（15t） | Unit Stand | 0.4 |
| | | Stone | 18pallet / unit | Container ship（20 feet） | Level stacked | 1.6 |
| | | | 110m$^2$/ unit | Flat truck with small crane（10t） | Level stacked | 1.6 |
| | Fittings | Aluminum curtain wall | — | Flat truck（4t） | Level placed | 0.2 |
| | | Glass | 69.0m$^2$/ unit | Flat truck（4t） | Unit Stand | 0.5 |
| | | Steel door | 57.6m$^2$/ unit | Flat truck（4t） | Level placed | 0.2 |
| | floor | OA floor・Free floor・sandwich floor | 200m$^2$/ unit | Flat truck（10t） | Unit Stand | 1.0 |
| | | Tile carpet | 760m$^2$/ unit | Flat truck（4t） | Unit Stand | 0.7 |
| | | PVC sheet | 1,300m$^2$/ unit | Flat truck（4t） | Level stacked | 0.8 |
| | Inner panel・ceiling | Gypsum board | 500m$^2$/ unit | Flat truck（4t） | Level stacked | 0.7 |
| | | Vinyl cloth | 1,800m$^2$/ unit | Flat truck（4t） | Level stacked | 0.6 |
| | | System ceiling | 69.12m$^2$/ unit | Flat truck（4t） | Unit Stand | 0.3 |
| | Equipment | Toilet | 40sets/ unit | Flat truck with jolo（4t） | Unit Stand | --- |

## Table 6. The judgements on A-type and B-type from the transportation states

| Processlevel | Capacity weight(ton) | Items | $\alpha$ (t/m$^3$) | $\beta$ (t/m$^3$) | CarriedPattern |
|---|---|---|---|---|---|
| Raw Material | 10 | Concrete | 2.3 | 2.2 | A |
| Intended material leve | 28 | Reinforcing | 7.8 | 0.7 | A |
| | 15 | Vinyl cloth | 0.6 | 0.7 | A |
| | | ALC | 1.6 | 0.7 | B |
| | 10 | Stone | 1.6 | 0.5 | A |
| | 4 | PVC sheet | 0.8 | 0.3 | A |
| | | Gypsum board | 0.7 | 0.3 | A |
| | | Form | 0.5 | 0.3 | A |
| | | Asphalt waterproofing | 0.1 | 0.3 | B |
| Building products level | 15 | Heat insulation sandwich panel | 0.4 | 0.7 | B |
| | 10 | OA floor | 1.0 | 0.5 | A |
| | 4 | Tile carpet | 0.7 | 0.3 | A |
| | | Glass | 0.5 | 0.3 | A |
| | | System ceiling | 0.3 | 0.3 | A |
| | | Toilet | — | 0.3 | B |
| Member level | 10 | Structural Steel | 1.1 | 0.5 | A |
| | 4 | Steel door | 0.2 | 0.3 | B |
| | | Aluminum curtain wall | 0.2 | 0.3 | B |




a)28ton truck b)15ton truck c)10ton truck d)4ton truck

## CONCLUSIONS

1)The type-of-packing patterns for building materials could be explained as Encapsulated type, Level stacked type, Unit Stand type and Level placed type.
2)The process levels for many kinds of building materials could be arranged as Raw Material level, Intended material level, Building products level and Member level.
3)The type-of-packing patterns and the process levels for many kinds of building materials would be deep relationship between each other.
4)The utilizing the relationship between the type-of-packing patterns between the process levels could be calculated from the bulk density of a cargo of vehicles and the total freight set as vehicles beforehand.
5)The type-of-packing pattern considering the process level could be classified into "A type( $\alpha \geqq \beta$ weight limited type)" and "B type( $\beta > \alpha$ volume limited type)" , and $\alpha$ is decided the value of bulk weight per unit volume of material/product and $\beta$ is decided the value of limited capacity of weight of career.
6)When assessing the environmental conditions of $CO_2$ emmitions related to these transportations for building materials, it is necessary to improve the estimation method in view of these type-of-packing patterns and the process levels toward the future.

## ACKNOWLEDGEMENT

This study was conducted as part of Grant-in-Aid for Young Scientist A (Masaki Tamura) of MOE, UDM Project of Kogakuin University No.3. The authors express their gratitude to their support.

## REFERENCES

M. Tamura and Y.Nachi, “Field Survey and Analysis on Transport Conditions of various Building Materials into Construction Site toward mitigating Environmental Impacts”, First International Conference of Concrete Sustainability(ICCS 13), 2013

Architectural Institute of Japan,“Recommendations for Environmentally Conscious Practice of Reinforced Concrete Building (in Japanese)”, 2008,

M. Tamura, “Supply/Demand Survey and In-transit Environmental Impact Evaluation of Aggregate for Concrete Conveyed to the Tokyo District”, fib-London, Concrete 21c.superhero, 2009

T.Noguchi, M.Tamura,2001, Concrete Design toward Complete Recycling, Journal of the fib Structural Concrete, Vol.2, Number 3: 155-167

ISO specifications, ISO 13315-1. “Environmental management for concrete and concrete structures, Part 1: General principles”, 2012,

ISO specifications, ISO 15932“ Sustainability in building construction -General Principles-”, 2008

ISO specifications, ISO 14044, “Environmental management - Life cycle assessment - Requirements and guidelines”, 2006

fib Task Group 3.6,“Environmental Design Guideline”, State-of-Art report of fib bulletin 31. 2007

Ministry of Land, Infrastructure, Transport and Tourism, 2004-2006, General technical report of the related Bureau(in Japanese), 2007