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Original article

A Systematic Cargo Securing Method for Non-Standard Cargoes on General Cargo Ships in Incheon Port

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Abstract

This study proposes a systematic cargo securing method for non-standard cargoes loaded on general cargo ships in Incheon Port. Despite the increasing transportation of non-standard cargoes with different shapes and characteristics, there are insufficient detailed securing standards, which frequently causes cargo damage and disputes among ship operators, shipping companies, and stevedores. In this study, international regulations including SOLAS and the CSS Code, as well as cargo securing manuals, were analyzed to establish systematic securing criteria for non-standard cargoes. In addition, external force calculations and safety factor criteria were applied to evaluate the securing safety according to vehicle weight categories. Based on the analysis, securing arrangements including the number and placement of lashing devices were proposed for each cargo weight range. The proposed securing methods were verified by comparing external forces and calculated securing strengths. The results confirm that the proposed methods can provide safe and practical securing standards for non-standard cargoes. Furthermore, the proposed approach is expected to contribute to the standardization of field operations, reduction of cargo damage, and prevention of disputes related to cargo securing.

Keywords: Non-standard cargo, Vehicle lashing, Cargo securing, General cargo ship, Lashing safety.

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1. Introduction

Incheon Port is one of the major trade ports in Korea and continuously handles various types of general and bulk cargoes (Incheon Port Authority, 2025). In particular, the transportation of non-standard cargoes such as used vehicles, heavy equipment, and special vehicles to Southeast Asian regions has been increasing on general cargo ships. However, because non-standard cargoes have different shapes, weights, and centers of gravity, it is difficult to apply standardized securing methods, and cargo securing operations are still highly dependent on the experience of field workers.

Current international conventions and related regulations require ships to carry a Cargo Securing Manual; however, detailed securing standards and methods for non-standard cargoes are not sufficiently specified. In actual ship operations, differences in securing practices among ship operators, shipping companies, and stevedores frequently result in cargo damage and liability disputes even for the same type of cargo.

Previous studies have investigated various cargo securing issues, including studies on problems and improvement measures for vehicle cargo handling operations (Kim et al., 2014), vehicle securing criteria for passenger ships operating in smooth water areas (Gang et al., 2020), and securing safety evaluations for coastal ferry vehicles in Korea (Choung et al., 2016a; Choung et al., 2016b; Lee, 2016; Jo, 2017). In addition, studies on container securing program development and securing system improvements for container ships (Shin et al., 2014; Kim, 2017), structural evaluations of container ship lashing bridges (Yun, 2008), and wind characteristic evaluations of ship transportation containers (Kim, 2017) have also been conducted. These studies mainly evaluated cargo securing safety through ship motion analysis and simulation-based external force calculations. However, most previous studies focused on standardized or semi-standardized cargoes such as containers, vehicle carriers, and ferries, while relatively few studies have addressed systematic securing standards for non-standard cargoes transported by general cargo ships. Despite the significant differences in shape and weight characteristics among non-standard cargoes, securing operations still largely depend on field experience, resulting in limitations in operational standardization and safety assurance.

Therefore, this study analyzes international regulations and Cargo Securing Manuals for non-standard cargoes exported from Incheon Port by general cargo ships. In addition, external force calculations and safety factor criteria are applied to establish systematic securing standards according to vehicle weight categories. By evaluating the safety of the proposed securing methods, this study aims to present practical securing standards applicable to field operations for non-standard cargoes.

2. Current Status of Incheon Port and Non-Standard Cargoes

Incheon Port is one of the major trade ports in Korea and serves as a central logistics hub for the metropolitan industrial region. Recently, the total cargo throughput of Incheon Port has continuously increased, from approximately 138,245 thousand RT in 2022 to approximately 145,316 thousand RT in 2024. Import cargo volume also increased from approximately 92,184 thousand RT in 2022 to 97,203 thousand RT in 2024, while export cargo volume increased from approximately 33,427 thousand RT to 35,882 thousand RT during the same period. In particular, Incheon Port is characterized by a high proportion of bulk and general cargoes, and the export volume of non-standard cargoes such as used vehicles, heavy equipment, and vehicle parts has also continued to increase.

Table 1: Recent Total Cargo Throughput of Incheon Port (Unit: 1,000 RT)

Division	2022	2023	2024
Total	138,245	141,872	145,316
Import	92,184	94,761	97,203
Export	33,427	34,598	35,882
Transshipment	1,124	1,205	1,338
Coastal	11,510	11,308	10,893

Source: Incheon Port Authority (2025), Major Statistics of Incheon Port 2025.

Note: The 2024 values represent finalized annual statistics.

Table 2: Incheon Port Bulk Cargo Volume (Unit: 1,000 RT)

Division	2022	2023	2024
Total	101,284	104,118	107,562
Import	71,203	73,114	75,228

Export	12,418	13,205	14,116
Transshipment	96	88	75
Coastal	17,567	17,711	18,143

Source: Incheon Port Authority (2025), Major Statistics of Incheon Port 2025.

Note: The 2024 values represent finalized annual statistics.

Table 3: Incheon Port Container Volume (Unit: 1,000 TEU)

Division	2022	2023	2024
Total	3,153	3,461	3,558
Import	1,561	1,706	1,772
Export	1,543	1,706	1,737
Transshipment	31	37	49
Coastal	18	12	-

Source: Incheon Port Authority (2025), Major Statistics of Incheon Port 2025.

Note: The 2024 values represent finalized annual statistics.

Although bulk cargoes such as petroleum products, coal, and mineral resources account for a large portion of cargo throughput at Incheon Port, the proportion of non-standard cargoes such as steel products, vehicles and vehicle parts, and machinery among export cargoes has also continuously increased. In particular, used vehicles, heavy equipment, and special vehicles are frequently transported by general cargo ships or bulk carriers using the Lo-Lo (Lift-on/Lift-off) loading method, requiring appropriate cargo securing methods according to cargo characteristics.

Table 4: Export Volume of Non-Standard Cargoes at Incheon Port (Unit: 1,000 RT)

Classification of Goods	2022	2023	2024
Steel and Steel Products	6,482	6,731	6,958
Vehicles and Vehicle Parts	5,884	6,115	6,403
Machinery	812	865	921
Heavy Equipment	547	593	648-
Scrap Iron	1,964	2,041	2,118
Chemical Industrial Products	1,538	1,621	1,704
Wood and Timber Products	1,285	1,214	1,173
Nonferrous Metals	268	291	315
Electrical Equipment and Components	74	88	96
Others	1,452	1,518	1,603

Source: Incheon Port Authority (2025), Major Statistics of Incheon Port 2025.

Note: The 2024 values represent finalized annual statistics.

As shown in Table 4, steel products and vehicles and vehicle parts were identified as representative non-standard export cargoes at Incheon Port, while machinery and heavy equipment cargoes also showed a continuous increasing trend. Because non-standard cargoes differ significantly in shape, weight, and center of gravity characteristics, it is difficult to apply uniform securing standards, and securing operations are often performed based on the experience of field workers.

Excessive securing may increase operational time and cost, whereas insufficient securing may cause cargo shifting and cargo damage. Therefore, systematic securing standards considering cargo characteristics are required to ensure safe loading and efficient cargo handling operations for non-standard cargoes.

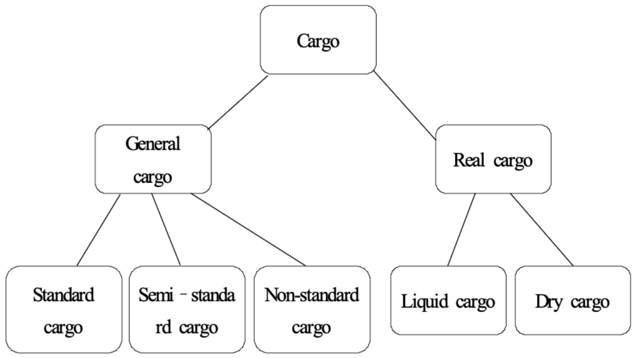

Figure 1: Classification of Cargoes

Ship cargoes can generally be classified into general cargoes and bulk cargoes according to packaging and loading characteristics. Bulk cargoes can further be divided into liquid cargoes and dry cargoes, while general cargoes can be classified into standard cargoes, semi-standard cargoes, and non-standard cargoes according to cargo shape and securing characteristics.

Standard cargoes refer to cargoes such as containers, whose shapes and loading methods are standardized and can therefore utilize standardized securing systems. Semi-standard cargoes refer to cargoes such as vehicles and trailers, for which standardized securing methods can be applied within a limited range. In contrast, non-standard cargoes require individual securing plans because their shapes, weights, centers of gravity, and structural characteristics differ significantly from one cargo type to another.

Non-standard cargoes refer to cargoes for which it is difficult to apply standardized loading and securing methods. Even within the same cargo category, sizes, weights, and structural characteristics often vary significantly, requiring different securing positions and numbers of securing devices depending on cargo characteristics. Representative non-standard cargoes include used vehicles, buses, trucks, heavy equipment, special vehicles, and industrial machinery.

In particular, non-standard cargoes are frequently transported by general cargo ships or bulk carriers using the Lo-Lo loading method. Because the center of gravity and cargo shape vary significantly among cargoes, securing operations require a high level of experience and safety evaluation. In addition, improper securing may cause cargo shifting, ship damage, and cargo accidents, making it important to establish systematic securing standards.

3. Review of Related Regulations

3.1 Regulations Related to Cargo Securing on Ships

The International Maritime Organization (IMO) and the SOLAS Convention require ships to prepare and maintain a Cargo Securing Manual to ensure the safe loading and securing of cargoes carried on board. As shown in Table 5, the SOLAS Convention and the IMO CSS Code provide principles for safe cargo stowage and securing to prevent cargo shifting caused by ship motion and external forces during navigation, and ships engaged in international voyages are required to perform cargo securing operations in accordance with these regulations.

Table 5: International Regulations Related to Cargo Securing

Regulation	Content
SOLAS	In accordance with SOLAS requirements and the CSS Code, ships engaged in international voyages shall ensure the safe stowage and securing of cargoes by maintaining appropriate cargo securing arrangements and procedures.
IMO CSS Code	The Code of Safe Practice for Cargo Stowage and Securing (CSS Code) provides general guidelines for the safe stowage and securing of cargoes, including the prevention of cargo shifting caused by ship motion and external forces during navigation.
IMO/MSC/Circ.745	This circular requires that the Cargo Securing Manual be maintained on board at all times and specifies that re-inspection by the classification society may be necessary when cargo types or dimensions are changed.
Cargo Securing Manual (CSM)	The Cargo Securing Manual provides detailed securing procedures, securing device arrangements, and allowable securing strengths according to ship and cargo characteristics.
Classification Society Rules	Classification societies provide technical standards for securing devices, lashing arrangements, and structural safety related to cargo securing systems on ships.
Port and Terminal Regulations	Port and terminal operators may establish additional cargo handling and securing procedures according to cargo characteristics and terminal operating conditions.

In addition, IMO/MSC/Circ.745 requires that the Cargo Securing Manual be maintained on board at all times and specifies that re-inspection by the classification society may be required when the type or size of cargoes changes. The Cargo Securing Manual should be prepared considering the strength and functions of securing devices according to ship and cargo characteristics and should ensure safety against dynamic and static external forces acting on cargoes.
However, current international regulations mainly provide general requirements for the preparation and maintenance of Cargo Securing Manuals and do not sufficiently specify detailed securing methods or standards for non-standard cargoes. In particular, securing operations for non-standard cargoes such as used vehicles, heavy equipment, and special machinery are often dependent on the experience of field workers because cargo shapes and centers of gravity vary significantly among cargoes.
Therefore, to ensure the safe transportation of non-standard cargoes, it is necessary to establish systematic securing standards based on international regulations while also reflecting actual field working conditions and cargo characteristics.

3.2 Safety Factor

The safety evaluation of cargo securing devices is a process used to verify whether cargoes can be safely maintained against ship motion and external forces occurring during navigation. The calculated securing strength of securing devices should be determined by applying a safety factor considering load imbalance among securing devices, improper assembly conditions, and possible strength reduction during operation.
In general, the calculated securing strength (CS) of a securing device is determined by applying a safety factor to the Maximum Securing Load (MSL) as follows.

$$CS = \frac{MSL}{1.5} \quad (1)$$

Here, CS represents the Calculated Strength of the securing device, and MSL represents the Maximum Securing Load. The safety factor of 1.5 is applied to account for dynamic loads, impact loads, and possible performance degradation of securing devices during ship operation.
Therefore, when establishing a cargo securing plan, it is necessary to consider not only the external forces acting on the cargo but also the allowable strength and safety factor of securing devices, thereby preventing cargo shifting and securing damage during navigation.

3.3 Calculation of Cargo Securing Forces and Securing Strength

The calculation of the Maximum Securing Load (MSL) of cargo securing devices is performed to evaluate whether cargoes can remain safely secured against external forces occurring during ship operation. Cargoes are subjected not only to accelerations caused by ship motion but also to external forces generated by wind pressure and waves, and appropriate securing strength should therefore be determined considering these forces.
External forces acting on cargoes in the longitudinal, transverse, and vertical directions are calculated based on cargo mass and ship motion accelerations, while additional external forces caused by wind pressure and waves are also considered as follows.

$$F(x,y,z) = m \cdot a(x,y,z) + Fw(x,y) + Fs(x,y) \quad (2)$$

Here, ($F(x,y,z)$) represents the external force acting on the cargo (kN), (m) represents the total cargo mass (t), ($a(x,y,z)$) represents acceleration caused by ship motion (m/s^2), ($Fw(x,y)$) represents external force

caused by wind pressure (kN), and ($Fs(x, y)$) represents external force caused by waves (kN).
Basic accelerations acting on cargoes vary according to cargo loading positions within the ship and can be classified into transverse, longitudinal, and vertical accelerations. Table 6 presents representative basic acceleration values according to deck location, showing that accelerations caused by ship motion generally increase toward upper deck and higher cargo positions. Therefore, cargo loading position is an important factor in determining the number and arrangement of securing devices.

Table 6 : Representative Basic Acceleration Values

Location	Transverse (m/s²)	Vertical (m/s²)
Upper deck	5.0~5.9	4.3~9.2
Second deck	5.4~6.2	4.3~9.2
Lower deck	6.1~6.7	4.3~9.2

Table 7 presents representative acceleration modification factors according to ship length and operating speed. In general, ship motion acceleration tends to increase as ship length decreases and operating speed increases, resulting in larger external forces acting on cargoes. Therefore, when establishing a cargo securing plan, appropriate acceleration modification factors should be applied considering ship dimensions and operating conditions.

Table 7: Representative Modification Factors According to Ship Length and Operating Speed

Ship Length (m)	12 knot	15 knot	18 knot
80	1.03	1.15	1.27
100	0.90	1.00	1.10
140	0.72	0.80	0.89
180	0.60	0.68	0.76

In particular, under small ship or high-speed operating conditions, dynamic loads acting on cargoes may increase, requiring additional safety evaluations for the number and arrangement of securing devices.

Table 8 presents representative correction factors for transverse acceleration according to changes in the B/GM ratio. In general, as the B/GM ratio decreases, ship rolling motion tends to increase, resulting in larger transverse external forces acting on cargoes. Therefore, when establishing a cargo securing plan, appropriate transverse acceleration correction factors should be applied considering the ship's stability characteristics.

In particular, ships with low B/GM ratios may experience increased transverse ship motion, which can increase the possibility of cargo sliding and overturning. Therefore, additional safety evaluations are required for the number and arrangement of securing devices.

In addition, because the effects of ship motion may vary depending on cargo loading position and deck height, external force variations according to cargo location should be comprehensively considered when establishing actual cargo securing plans.

Table 8: Representative Correction Factors for Transverse Acceleration According to B/GM Ratio

B/GM	Upper Deck	Second Deck	Lower Deck
7 m	1.15	1.26	1.42
10 m	1.06	1.09	1.14
13 m	1.00	1.00	1.00

To evaluate cargo securing safety, equilibrium calculations for cargo sliding and overturning should be performed in addition to evaluating external forces acting on cargoes. During ship operation, cargoes are simultaneously subjected to transverse, longitudinal, and vertical external forces, which may cause cargo shifting and overturning. Therefore, securing devices should be capable of sufficiently resisting the external forces and moments acting on cargoes.
Sliding equilibrium calculations are performed considering the frictional force between the cargo and deck surface as well as the calculated securing strength of securing devices. In general, the transverse external force should be smaller than the frictional resistance and effective securing strength, and can be expressed as follows.

$$Fy \leq \mu \cdot m \cdot g + CS_1 \cdot f_1 + CS_2 \cdot f_2 + \cdots\cdots\cdots + CSn \cdot fn \tag{3}$$

Here, (Fy) represents the transverse external force (kN), (μ) represents the friction coefficient, (m) represents cargo mass (t), (g) represents gravitational acceleration (9.81m/s^2), (CS) represents the calculated securing strength of securing devices (kN), and (f) represents a function value according to securing angle.
In addition, overturning equilibrium calculations are performed by comparing the overturning moment generated by the cargo center of gravity and external force application point with the restoring moment generated by securing devices and cargo self-weight. Cargo safety can be ensured only when the overturning moment is smaller than the restoring moment.
Table 9 presents representative friction coefficients between cargoes and deck surfaces as well as securing angle factors. In general, higher friction coefficients increase resistance against cargo sliding, while securing angles significantly influence the effective strength of securing devices. Therefore, appropriate friction coefficients should be applied considering cargo material and deck surface conditions.

Table 9: Representative Friction Coefficients and Securing Angle Factors

Condition	Friction Coefficient (μ)	Securing Angle Factor (f)
Steel / Steel	0.10	0.75
Steel / Wood	0.30	0.75
Rubber / Steel	0.50	0.75
Rubber / Wood	0.60	0.75

In particular, because non-standard cargoes differ significantly in shape and center of gravity characteristics, it is difficult to apply uniform securing standards. Therefore, external force and moment equilibrium calculations considering actual cargo characteristics and loading positions are required. This approach can help prevent cargo shifting and cargo damage during navigation.

The equilibrium calculation for transverse tilting is performed by comparing the overturning moment generated by transverse external forces acting on the cargo with the resisting moment generated by cargo self-weight and securing devices. In general, the following condition should be satisfied.

$$Fy \cdot a \leq b \cdot m \cdot g + CS_1 \cdot f_1 + CS_2 \cdot f_2 + \cdots\cdots\cdots + CSn \cdot fn \tag{4}$$

Here, (Fy) represents the transverse external force (kN), (a) is the overturning lever arm (m), (b) is the stability lever arm (m), (m) is the cargo mass (t), (g) is the gravitational acceleration (9.81m/s^2), (CS) represents the calculated securing strength of securing devices (kN), and (c) is the resisting lever arm of securing devices (m). This equation means that the overturning moment generated by transverse external forces should be smaller than the resisting moment generated by cargo self-weight and securing devices. Therefore, for non-standard cargoes with high centers of gravity or irregular shapes, stability against tilting should be evaluated together with sliding stability.

In addition, cargoes may experience longitudinal sliding due to pitching motion and longitudinal acceleration of the ship, requiring longitudinal equilibrium calculations. In particular, longitudinal external forces generated by sudden speed changes and wave impacts may cause cargo shifting.
Longitudinal sliding equilibrium calculations are performed by comparing longitudinal external forces with the resisting forces generated by cargo weight and securing devices, and the following condition should generally be satisfied.

$$Fx \leq \mu \cdot (m \cdot g \cdot Fz) + CS_1 \cdot f_1 + CS_2 \cdot f_2 + \cdots\cdots + CSn \cdot fn \tag{5}$$

Here, (Fx) represents the longitudinal external force (kN), (μ) represents the friction coefficient, (m) represents cargo mass (t), (g) represents gravitational acceleration (9.81m/s^2), (CS) represents the calculated securing strength of securing devices (kN), and (f) represents a function value according to securing angle.
Therefore, the number and arrangement of securing devices should be determined so that longitudinal external forces do not exceed the frictional resistance between cargo and deck surfaces and the resisting forces of securing devices.
The representative acceleration values and correction factors used in this study were established based on the IMO CSS Code and practical cargo securing guidelines commonly applied in field operations.

4. Systematization of Securing Methods for Non-Standard Cargoes

Non-standard cargoes differ significantly in shape, weight, and center of gravity characteristics, making it difficult to apply uniform securing standards. In particular, cargoes such as used vehicles, heavy equipment, and special vehicles may require different numbers and arrangements of securing devices depending on cargo characteristics. Therefore, systematic securing standards considering cargo weight and loading characteristics are required to ensure safe transportation of cargoes.
In this study, the number and arrangement standards of securing devices according to vehicle weight were proposed for vehicle-type non-standard cargoes. In addition, appropriate securing methods for each cargo category were systematized by comparing external forces acting on cargoes with the calculated securing strength of securing devices.
Securing methods according to vehicle weight were proposed considering both cargo safety and operational efficiency. Through this approach, practical securing standards applicable to actual field operations are presented for non-standard cargoes.
Table 10 presents the recommended securing methods, number of lashings, maximum external forces, proposed securing strengths, and applicable cargo categories according to vehicle weight. In general, as vehicle weight increases, external forces generated by ship motion also increase, requiring additional securing devices and reinforced securing arrangements. Additional stoppers and reinforced securing arrangements may also be required depending on cargo shape and center of gravity characteristics.

Table 10: Proposed Securing Methods According to Vehicle Weight

Vehicle Weight	Recommended Securing Method	NO. of Lashing	Maximum External Force	Proposed Securing Strength	Remarks
Less than 2 tons	Wheel stopper + Wire rope securing	4 Points	41.44 kN	61.41 kN	Passenger cars and small vehicles
2-5 tons	Wheel stopper + Cross wire securing	4 Points	62.37 kN	92.21 kN	Vans and small trucks
5-10 tons	Cross wire securing + Chain lashing	4~6 Points	105.4 kN	115.4 kN	Medium trucks and buses
11-15 tons	Chain lashing + Reinforced securing	6 Points	124.9 kN	137.8 kN	Heavy trucks and construction equipment
16-28 tons	Reinforced chain securing + Additional stopper	8-10 Points	212.2 kN	223.9 kN	Heavy equipment and special cargoes

The proposed securing strengths presented in Table 10 were calculated using representative Maximum Securing Load (MSL) values specified in the Cargo Securing Manual (CSM). A safety factor of 1.5 was applied to determine the Calculated Strength (CS). The calculations were performed using the representative friction coefficients and securing angle factors shown in Table 9 under typical steel deck conditions. Representative acceleration values and modification factors presented in Tables 6–8 were consistently applied to all vehicle weight categories.

Example (5–10 ton vehicle)
Vehicle weight: 8 ton
Maximum external force: 105.4 kN
Proposed securing strength: 115.4 kN
Since the proposed securing strength (115.4 kN) exceeds the required external force (105.4 kN), the securing arrangement satisfies the safety criterion.

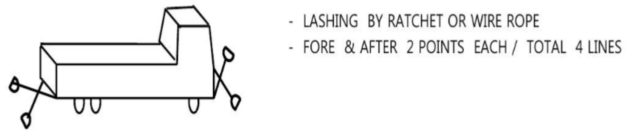

Figure 2: Recommended Lashing Method for Vehicles under 2 Tons

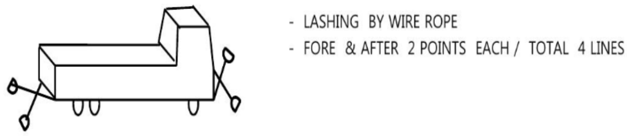

Figure 3: Recommended Lashing Method for Vehicles between 2 and 5 Tons

For vehicles weighing less than 2 tons, 4-point wire securing together with wheel stoppers was applied, providing a securing strength of 61.41 kN against a maximum external force of 41.44 kN. In addition, for vehicles weighing between 2 tons and 5 tons, 4-point securing using cross wire securing and wheel stoppers was applied, providing a securing strength of 92.21 kN against a maximum external force of 62.37 kN.

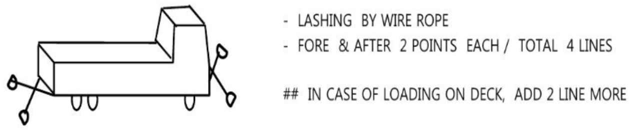

Figure 4: Recommended Lashing Method for Vehicles between 5 and 10 Tons

For vehicles weighing between 5 tons and 10 tons, 4-6-point securing using wire and chain securing arrangements was applied, providing a securing strength of 115.4 kN against a maximum external force of 105.4 kN. Furthermore, for vehicles weighing between 11 tons and 15 tons, 6-point reinforced chain securing arrangements were applied, providing a securing strength of 137.8 kN against a maximum external force of 124.9 kN.

Figure 5: Recommended Lashing Method for Vehicles between 11 and 15 Tons

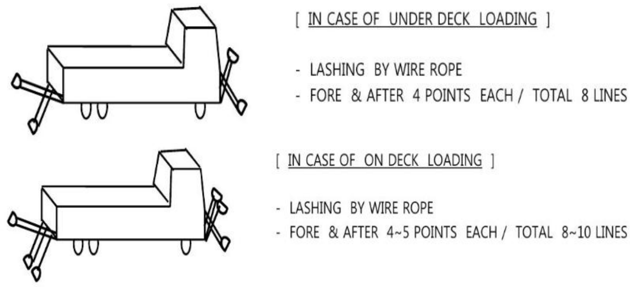

Figure 6: Recommended Lashing Method for Vehicles between 16 and 28 Tons

For vehicles weighing between 16 tons and 28 tons, 8-10-point securing using reinforced chain securing arrangements and additional stoppers was applied, providing a securing strength of 223.9 kN against a maximum external force of 212.2 kN. In particular, heavy cargoes may experience significantly increased transverse and longitudinal external forces caused by ship motion, requiring additional chain lashings and stoppers to prevent cargo shifting.

In all vehicle weight categories, the proposed securing strengths were greater than the maximum external forces acting on the cargoes, confirming that the proposed securing methods can provide sufficient safety.

The proposed securing standards are intended for typical general cargo ships transporting vehicle-type non-standard cargoes under normal operating conditions. The proposed arrangements assume conventional steel deck surfaces, standard lashing angles, and representative cargo loading positions. Cargoes with unusually high centers of gravity, irregular geometry, or exceptional loading conditions should be individually evaluated and may require additional securing devices beyond the proposed recommendations.

5. Conclusions

This study analyzed the current status of non-standard cargoes handled at Incheon Port and reviewed international regulations related to cargo securing, while also systematizing securing methods for vehicle-type non-standard cargoes. Incheon Port serves as a major industrial and logistics hub in the Seoul metropolitan area, handling large volumes of bulk cargoes and general cargoes, with non-standard cargoes continuously increasing in variety and quantity. However, current international regulations do not sufficiently provide detailed securing standards for non-standard cargoes, and actual securing operations are often dependent on the experience of field workers.

Accordingly, this study proposed recommended securing methods and securing device arrangements according to vehicle weight categories based on external forces caused by ship motion, safety factors, and calculated securing strengths of securing devices. In addition, securing safety was evaluated through longitudinal and transverse external force calculations as well as overturning and tilting equilibrium analyses.

The results showed that external forces acting on cargoes increase as vehicle weight increases, requiring additional chain lashings and reinforced securing arrangements. Furthermore, in all vehicle weight categories, the proposed securing strengths were greater than the maximum external forces acting on the cargoes, confirming that the proposed securing methods can provide sufficient safety.

The securing standards for non-standard cargoes proposed in this study are expected to be practically applicable in actual field operations. The proposed securing standards are expected to contribute to the standardization of cargo securing practices for non-standard cargoes and improve operational safety in general cargo shipping. This is expected to improve the consistency and reliability of cargo securing practices in general cargo shipping.

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