A Case Study on the Fire of Factory Buildings in Korea

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Abstract

According to the fire statistics of the Ministry of Home Affairs, the fire ratio in factories, work places and warehouses shows 21.5% among total fire of buildings except the fire on cars or other fires. Especially, the buildings like factories and warehouses, which have a lot of ignitable sources and thus always have a strong possibility of fire, are needed to have well planned strategy in terms of life safety and property protection. In this respect, the present paper analyses the existing fire cases in factories, finds out the fire properties of factory buildings, and evaluates the codes concerning fire resistance and fire severity.

Introduction

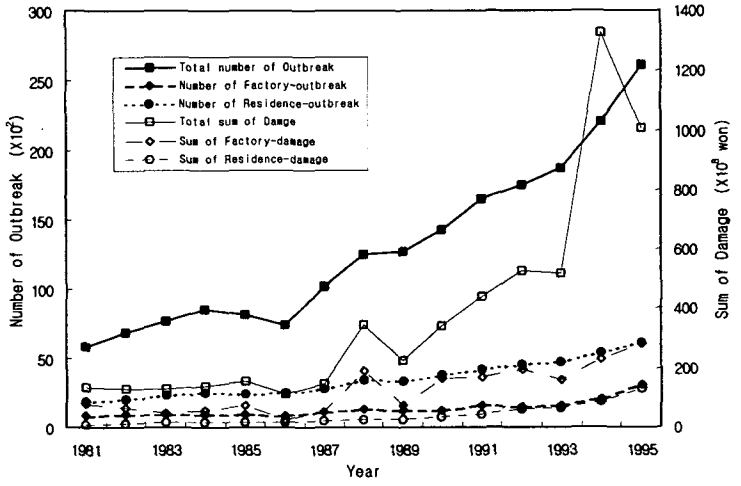
To clarify every dangerous element concerning a facility is necessary to reduce the potential danger which can be easily neglected. Fire risk resides in the outside ignitable sources or the weakness of the facility itself. The elements causing the fire risk are ; the faulty design or construction, mistaken operations, the malfunction or break of facilities, deficient maintenance, insufficient supervision and training, environmental elements, natural elements, etc.
The fire risk can be divided into ignition and fire spread. The danger of ignition depends on the kind of ignition sources and their management, and the danger of fire spread relies on the structure and the use of the building.
According to the fire statistics of the Ministry of Home Affairs in 1995, the fire ratio of factories, work places and warehouses account for 21.5% of all fire incidents and the financial damage is enormous. In particular, buildings such as a factory and a warehouse, which have lots of combustibles and thus have higher possibility of fire, need fire proof installation in terms of life safety and property protection.
In this respect, the present study tries to analyse the fire cases, find out the fire properties and finally contribute to the fire safety strategy of factory buildings

Statistics and Case Study of the Fire of Factory Buildings

Statistics

According to the fire statistics surveyed by the Ministry of Home Affairs in 1996, the fire ratio of factories (except work place and warehouse) and houses (except multi-family housing) account for 11.6% (3,031 incidents) and 23.5% (6,118 incidents) respectively of all 26,071 fire incidents. As for the financial loss, the ratio of factories shows 28%, whereas houses 12.8%.

The figure 1 shows that the factory fire is 10 times more than house fire in terms of the financial loss per a fire. At a glance, such a fact can be seen as certain if we compare the scale of a factory and a house. However, it can be also said that it results from the total destruction by fire because a factory has lots of movable property as seen in the case study.



[Figure 1] Trend of Fire Incidents and Financial Loss

Case Study of Factory Buildings

Twelve major factory fires broken between 1974 and 1994 are shown as follow;

(1) Y. Spinning Co.

a. Building Structure R.C. structure, Single story, Total floor area; 65,340㎡, Roof; steel truss, Exterior wall; cement block, Ceiling; plywood+insulation board(EPS)

b. Fire Situation Ignited at about 15:45, Jan. 23 1974. At first, a fluorescent light became overheated and it ignited cotten dust. The fire spread over the cotten dust and the plywood of the ceiling. The fire extended to the whole building within 20 min. after the ignition because of deficient compartment and the combustion of raw materials and goods in store. The fire spread the 5.32m high ceiling at first and the early extinguishing of the fire was failed because of the frozen fire extinguisher and the dried water tank in the factory.

c. Problem deficient compartments within the factory ; combustible finish materials such as plywood ; fiber dust and cotten dust as a major cause of fire spread.

(2) H. Synthetic Fiber Co. Masan Factory

a. Building Structure R.C. structure, Two story, Total floor area; 17,850㎡, Roof; slate on steel truss, Exterior wall; cement block, Ceiling; plywood+insulation board(EPS)

b. Fire Situation Ignited at about 05:40, May 24 1975. The electrical spark of the power switch ignited the nearly stored acryl manufactured goods. The ignition of the synthetic fiber made the early extinguishing failed. Then, the combustion of the ceiling and interior materials made the fire spread horizontally in a very short time.

c. Problem Using the combustible finish materials on the ceiling and the combustion and falling down of the ceiling were major causes of fire spread.

(3) G. Co. Changwon Factory

a. Building Structure R.C. structure, Two story, Total floor area; 26,603㎡, Roof; slate on steel truss, Exterior wall; cement block, Ceiling; plywood+insulation board(EPS)+slate
b. Fire Situation Ignited at about 03:40, Dec. 23 1979. The electricity overheating in the work place ignited near combustible materials. The combustion of goods hung on the ceiling travel conveyer, the ceiling fire proofs and combustible interior materials spread horizontally, and finally extended to the whole factory.
c. Problem The smoke and poisonous gas from the ceiling fire proofs and combustible interior materials hindered extinguishing activities ; deficient compartments ; the collapse of the ceiling made the fire spread and finally the building fell down.

(4) P. Spinning Co. Sintangin Factory
a. Building Structure R.C. structure, Total floor area; 17,850㎡, Roof; slate on steel truss, Exterior wall; masonry structure, Ceiling; EPS board+plywood
b. Fire Situation At about 04:00, Oct. 13 1983, The fuel of a boiler burner in the work place leaked out and ignited around combustible materials. In extinguishing the fire power failure made the fire plug dead so that the early extinguishing was failed. The fire ignited combustible materials like EPS board inside the ceiling. The flying sparks of fire ignited combustible materials on the floor so that it caused rapid horizontal spread. The combustible materials on the 1st floor with broken materials of columns, walls and so on fell down to the underground floor so that it caused the vertical spread. High temperature made the exposed steel deformed and thus the wall fell down. Finally extinguishing work became impossible.
c. Problem The major structural parts like column, beam and roof frame were without the fire proof coating. It caused falling down of the building. The ceiling consisted of combustible materials like polyethylene form and plywood, which resulted in generating combustible gas and falling down of the combustible materials. It caused the fire spread.

(5) I. Spinning Co. Kwangju Factory
a. Building Structure Steel structure, Single story, Total floor area; 13,675㎡, Roof; steel truss, Exterior wall; bricks, Ceiling; plywood+insulation board(EPS)
b. Fire Situation At about 04:40, Dec. 7 1983, Electric leakage on the ceiling in the work place caused ignition. The fire ignited combustible roof materials and raw materials stored around. During the fire, the inside and outside fire plug were dead so that the early extinguishing was failed. Ignited plywood fell down to the floor, which spread to goods. The falling down of columns, beams and roof frame by high temperature made the extinguishing work impossible.
c. Problem The ceiling consisted of combustible materials like plywood, which resulted in the fire spread. The major structural parts were without the fire proof coating. It caused falling down of the building.

(6) T. Industrial Co.
a. Building Structure R.C. and Steel structure, Two story, Total floor area; 32,904㎡, Column; steel lattice, Roof; R.C. slab, Exterior wall; cement block, Ceiling; plywood+vinyl+vermiculite
b. Fire Situation At about 12:45, Apl. 28 1985, by breaking a start lamp of fluorescent light it ignited dust and ceiling plywood. The early extinguishing of fire was failed. Inflaming on acryl fiber, the fire rapidly spread in horizontal direction. The fire extended to the whole building within 12 min. after ignition because of the combustion of ceiling plywood and dust on ceiling. The steel truss of 2nd floor was collapsed by the loss of strength which resulted from the rapid development of 1st floor fire. And it extended to the 2nd floor.
c. Problem The ceiling consisted of combustible materials like plywood, which resulted in the fire spread and occurred toxic gases. The major structural parts were without the fire proof

coating. It caused falling down of the building.
(7) D. Rubber Industry Co.
a. Building Structure R.C. and Steel structure, Roof; steel truss+slate, Exterior wall; cement block, steel+slate
b. Fire Situation Ignition occurred in a work space on the 1st floor at about 06:16, Feb. 4 1988. It spread over raw materials with high inflammability (rubber, sponge) and then over the ceiling. It extended to the 2nd floor through a staircase.
c. Problem the use of combustible materials ; deficient compartment.

(8) D. Automobile Co.
a. Building Structure Steel structure, Two story with a basement, Total floor area; 9,499㎡, Column; H type steel, Roof; steel truss+color sheet steel plate, Exterior wall; concrete block+ color sheet steel plate
b. Fire Situation Ignition started in a warehouse at about 18:03, Nov. 28 1987. Combustion of package materials with ignitability extended over the whole building. Although the inside concrete wall retarded the fire spread, the overall deficiency of compartment design caused the whole building fire. The high temperature made the outside wall of steel structure and the roof frame very weak and finally the building collapsed.
c. Problem Deficient compartment; failure of early extinguishment ; structural elements with no fire proof coating

(9) I. Spinning Co.
a. Building Structure Masonry structure, Single story, Total floor area; 14,126㎡, Roof; slate on Steel truss, Ceiling; hardboard
b. Fire Situation At about 01:45, March 30 1990, ignition started inside the air-jet of a production machine. It extended to near machines and the ceiling. The fire spread proceeded rapidly through fiber debris and air-jet. Deficient compartment and the collapse of the roof made active extinguishing work difficult. Openings were few for the control of temperature and humidity of the interior so that the release of smoke and toxic gas was impossible. Combustible materials inside like hardboard on the ceiling accelerated fire spread.
c. Problem Few openings made the release of smoke and toxic gas with high temperature impossible ; the use of combustible ceiling materials ; deficient compartment; insufficient training and education on fire safety.

(10) D. Electronic Co.
a. Building Structure Steel structure, Two story, Total floor area; 49,500㎡, Roof; steel truss+ steel plate, Exterior wall; P.C. and steel plate Ceiling; plywood+insulation board(EPS)
b. Fire Situation At about 05:10, Oct. 21 1990, electrical leakage occurred in the resources warehouse. At first, the combustion of plastics produced smoke and toxic gas, which made early extinguishment failed. Deficient compartment; the combustion of combustion of insulation board(EPS) such as plywood, paint and EPS board; the role of the ducts and conveyer belts as a route for fire spread; The building was collapsed by the loss of support stress which resulted from the heat of steel members such as columns, beams and the roof.
c. Problem Deficient compartment; roof insulation board(EPS) ; the role of the ducts and conveyer belts as a route for fire spread ; structural elements with no fire proof coating ; the reduction of acting range of fire brigade by large buildings resulted from unreasonable extension.

(11) C. Spinning Co
a. Building Structure R.C. structure, Single story, Total floor area; 102,240㎡, Column and

Beam; R.C. H type steel, Roof; slate on steel truss+asphalt roofing+EPS board+rock wool+PE film+plywood, Exterior wall; brick+EPS board+cement block, Ceiling; plywood+EPS board+slate
b. Fire Situation At about 17:20, Dec. 11 1992, a electrical spark started fire. Combustible materials like EPS board and old plywood and dust were ignited and extended. The fire extended over the whole building through the ceiling space. The falling down of combustible materials from the ceiling caused the rapid growth of fire and the production of smoke and toxic gas. In addition, steel structure roof frame with no fire proof coating was collapsed made the extiguishiment work impossible.
c. Problem The failure of early fire extinguishment; Deficient compartment ; combustible interior materials ; structural elements with no fire proof coating ; the high fire load of goods and raw materials.

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(12) Y. Chemical Co.
a. Building Structure R.C. structure Column; H type steel, Roof; vinyl coating on without fire proof coating steel truss
b. Fire Situation At about 00:05, Aug. 4 1994, ignition occurred in the ceiling of an office on the 2nd floor. The fire spread over the insulation board(EPS) in the ceiling, production samples, furniture, equipments, electrical lines in the ceiling of the next laboratory, and the lagging materials of pipes. Fused insulation board(EPS) fell down to the floor so that the fire extended to foaming agent materials and goods stored on the 1st floor in the factory and finally over the whole building. The fire spread over the whole factory buildings merely took about 20 minutes.
c. Problem the fusion and the combustion of insulation board(EPS) of synthetic high polymer; the high fire load of combustible interior materials, goods and raw materials; deficient compartment; the bad management of fire protection facilities.

Fire Properties Analysis

Unlike other buildings, a factory fire is characterized by burning down almost everything if early discovery or extinguishment is failed. Compared to other buildings, a factory has several inherent features ; high fire load, loosened regulations on fire protection compartment from the view point of factory work and its process, neglecting the combustible materials. It is seen from the case study, the fire properties of the factory buildings have certain relationship to their structure, fire process and damage. That is, no fire proof coating on columns, beams and roof frame in most factory buildings result in fire spread and difficult extinguishing work by the collapse of important structural elements, in particular, roof frame because of high temperature. Most large factories with large area of steel truss frame roof or steel structure are often omitted fire protection compartments in the viewpoint of work process. It usually causes the collapse of major structural elements and fire spread.

In the case of fire in factory buildings, specific features different from other fires is fire spread over the structure of the ceiling and the roof. The heat produced by fire is accumulated in the ceiling or in the lower part of the roof so that it ignites the insulation board(EPS) of the roof or combustible materials. It means fire spread over the whole building and the collapse of the ceiling and the roof structure.

In a large factory, in case that major structural elements like columns, beams and roof frame are constructed in steel structure or reinforced concrete, and the roof consists of slate and metal plate+water proof materials+synthetic high polymers insulation board(EPS)+metal plate and plywood, the metal plate is heated by high temperature and thus the falling down and

fusing of the insulation board(EPS), and it produces toxic gases. In case that the ceiling finishes are made up of combustible materials. It offers a major cause of fire spread and the collapse of the ceiling and the roof structure.

The result of the case study analysed above shows that early discovery and early extinguishment are important factors to be able to reduce damage. In the case of most factories, it is seen that fire spread over the whole building within about 10~20 min. after ignition. In order to prevent this, the use of incombustible materials, a night patrol or a private fire brigade are important.

In terms of building structure, fireproof treatments of interior materials and proper compartment are necessary in order to prevent fire spread. insulation board(EPS) used on the roof, the ceiling and some walls, and the fire proof coating of major structural elements should be chosen carefully by considering its chemical properties to prevent combustible and toxic gases.

Conclusion

By analysing the major fires of factory buildings occurred between 1974 and 1994, some results obtained are as follow;

(1) The spreading speed of early fire is increased by using combustible materials as the interior materials of the building so that early extinguishment is hindered. In addition, the loosened regulations on compartment made the whole building collapse in many cases.

(2) In the case of large factories and steel structure buildings, it can be suggested that most collapsed buildings are resulted from deficient fire proof coating on major structural elements.

(3) As buildings become more complex and larger, appropriate scale and proper compartment are needed. In spite of such a fact, proper compartment is often not designed by being treated as unnecessary. In fact, it causes the fire spread over the whole building.

(4) Most buildings collapsed after ignition result from deficient fire proof coating for major structural elements. The heat produced by fire is accumulated in the upper part of the interior space. It builds up a gas layer of high temperature and it acts as a factor causing fire spread over the whole space. In addition, it also increases the possibility of collapsing by decreasing stress of the upper part structure. Therefore, it is suggested that a way which combustible gas with high temperature can be discharged automatically, should be introduced, and the provision of minimum fire resistance should be obligatory.

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