DESIGN AND PERFORMANCE ISSUES RELATING TO LIGHT MANUFACTURING FACILITIES 8

8.1 INTRODUCTION

This chapter addresses a broad range of facilities used for industries engaged in the manufacturing assembly, testing and packaging of specialized products within workbench production areas. Much of this manufacturing is associated with the electronics, or “high-tech” industry, and in some cases, special environments such as “clean-rooms” are required. Most light manufacturing operations are relatively new and take place in recently designed and constructed buildings using modern equipment installations.

The following are some unique issues associated with light manufacturing facilities that should be kept in mind during the design and construction phase of new facilities:

- Protection of building occupants is a very high priority.

- Building occupancy is relatively low, except in buildings with major production or assembly functions. Occupants are predominantly work-force, with high daytime "8 am to 5 pm" occupancy, although favorable market conditions may entail the use of additional work-shifts. Visitors are few in number.
- Ensuring the survival of production, testing and other expensive equipment is an important economic concern.
- Closure of the building for any length of time represents a very serious business problem, which will involve loss of revenue and possibly loss of market share.
- Most manufacturing building occupants are generally familiar with the characteristics of their building; a small percentage may be disabled to some degree.
- Frequent provision must be made for the production of new products and the removal of existing equipment and its replacement.
- Ensuring the survival of business records, whether in electronic or written form, is essential for continued business operation.

8.2 OWNERSHIP, FINANCING AND PROCUREMENT

Many light manufacturing facilities are owner developed, particularly if owned by national or global corporations, but some are also developer owned providing for tenant operations. Some large corporations may use a developer to build facilities that suit their operations, and thus avoid becoming involved in possibly troublesome development and building operations. Buildings that are constructed by developers as speculation tend to be occupied by start-up or young companies. In these instances the developer and building designers provide an empty "shell," which is fitted out according to the tenants' planning, spatial and environmental needs; design and construction is generally undertaken by the tenant's designers and subcontractors. This tends to split the responsibility for interior nonstructural and other risk-reduction design and construction measures between the building designers and contractor, and the tenant designers and contractors.

Financing for these facilities is typically through private loans. The effective life of the building may be about 50 years, particularly in the electronic industry. Light manufacturing buildings are generally constructed using a single contractor selected by competitive bid. Low cost and very rapid construction, with reliable achievement of construction schedules, are prime considerations.

8.3 PERFORMANCE OF LIGHT MANUFACTURING FACILITIES IN PAST EARTHQUAKES

Starting in the late 1950s larger light manufacturing buildings have been predominantly tilt-up structures, particularly in California. In seismic regions the perimeter precast walls were used as shear walls and roof structures were generally glued-laminated beams and plywood diaphragms. In the 1964 Alaska earthquake and the 1971 San Fernando (Los Angeles) event, performance of these buildings was poor, with considerable damage being sustained. The most common type of failure was to the wall/diaphragm anchors, but large out-of-plane movement of the panels, out-of-plane bending cracks in pilasters at mezzanine levels, and roof separations were all encountered and many roof collapses occurred. Due to the relatively large size of these buildings roof collapses were localized, rarely extending beyond one or two bays, and the buildings were sparsely occupied, so casualties were few. (Figure 8-1)

Following the 1971 San Fernando earthquake code changes were introduced, with the result that subsequent performance was improved. During the 1994 Northridge earthquake near Los Angeles, there were a number of failures of tilt-up structures and there were some collapsed wall panels along the sides of buildings resulting in partial roof collapse.

Figure 8-1 Roof and wall collapse of tilt-up building during the 1994 Northridge earthquake. (Photo courtesy of the Earthquake Engineering Research Institute)

Changes to wall anchorage requirements were introduced in the 1997 *Uniform Building Code.*

8.4 PERFORMANCE EXPECTATIONS AND REQUIREMENTS

The following guidelines are suggested as seismic performance objectives for light manufacturing facilities:

- Persons within and immediately outside manufacturing facilities must be protected at least to a life-safety performance level during design-level earthquake ground motions.
- Building occupants should be able to evacuate the building quickly and safely after the occurrence of design-level earthquake ground motions.
- Emergency systems in the facility should remain operational after the occurrence of design-level earthquake ground motions.
- Emergency workers should be able to enter the building immediately after the occurrence of design-level earthquake ground motions, encountering minimum interference and danger.
- Key manufacturing equipment, supplies and products should be protected from damage.
- In "high-tech" manufacturing facilities most services and utilities should be available within three hours of the occurrence of design-level earthquake ground motions.
- There should be no release of hazardous substances as a result of the occurrence of design-level earthquake ground motions.

8.5 SEISMIC DESIGN ISSUES

The information in this section summarizes the characteristics of light manufacturing facilities, notes their relationship to achieving good seismic performance, and suggests seismic risk management solutions that should be considered.

Seismic Hazard and Site Issues

RISK CONSIDERATION

Unusual site conditions, such as a near-source location, poor soil characteristics, or other seismic hazards, may lead to lower performance than expected by the code design.

Unusual site conditions, such as a near-source location, poor soil characteristics, or other seismic hazards, may lead to lower performance than expected by the code design. If any of these other suspected conditions are geological hazards, a geotechnical engineering consultant should conduct a sitespecific study. If defects are encountered, an alternative site should be considered (if possible) or appropriate soil stabilization, foundation and structural design approaches should be employed to reduce consequences of ground motion beyond code design values, or costly damage caused by geologic or other seismic hazards (see Chapter 3 for additional information). If possible, avoid sites that lack redundant access and are vulnerable to bridge or highway closure.

Structural System Issues

Light manufacturing facilities are usually one story; sometimes office/ administrative accommodation is provided in a mezzanine space. There has been increasing use of light steel frames and steel deck structure for roofs and mezzanines. Most large buildings now use braced steel frame structures. Exteriors may be of masonry or metal insulated panels.

Manufacturing buildings are intrinsically simple in their architectural/ structural configuration, and basically are large open box-like structures with few interior walls and partitions. This enables their structural design to be simple, and their seismic design can be carried out using the basic equivalent lateral force analysis procedures with a good probability of meeting code performance expectations as far as life safety is concerned. The desire for low cost, however, coupled with a tendency to meet only the minimum code requirements sometimes results in inadequately engineered and poorly constructed structures, The protection of valuable equipment and contents requires structural design to a higher performance level.

The large building size and long-span light frame load bearing structures of many of these facilities often lead to large drifts (or sway). When designed to code minimums these drifts may be excessive and cause nonstructural damage, particularly to ceilings and partitions.

Nonstructural System Issues

RISK CONSIDERATION

Continued operation is particularly dependent on nonstructural components and systems

Continued operation is particularly dependent on nonstructural components and systems, including purchased equipment, much of which is often of great sensitivity and cost. Many specialized utilities must be provided, some of which involve the storage of hazardous substances, such as pharmaceuticals, or hazardous gases. These must be protected against spillage during an earthquake. Distribution systems for hazardous gases must be well supported and braced.

The extensive use of light-steel-frame structures for manufacturing facilities, together with the tendency for them to be designed to minimum codes and standards, has resulted in structures that are subject to considerable drift and motion. As a result, recent earthquakes have caused a high level of nonstructural damage, particularly to ceilings and lighting. This kind of damage is costly and its repair is disruptive.

Research and production areas may need special design attention to specialized equipment services and materials to ensure continued production and delivery.

In most manufacturing facilities the building structure forms only a weatherproof cover and is lightly loaded. Often there is no suspended ceiling and light fixtures are hung directly from the building's structure. In storage areas, materials are stacked on metal storage racks that provide their own vertical and lateral support.   These racks are supplied and installed by specialist vendors. The correct sizing and bracing of these racks are critical if the materials are heavy and located at a high elevation. Even if the racks remain stable, material may be displaced and fall on the aisles or on equipment

Storage units, free standing work stations, and filing cabinets are also subject to upset. Excessive drift and motion may lead to damage to rooftop equipment and localized damage to water systems and fire suppression piping and sprinklers.

The responsibilities within the design team for nonstructural component support and bracing design should be explicit and clear. The checklist for responsibility of nonstructural design in Chapter 12 (see Figure 12-5) provides a guide to establishing responsibilities for the design, installation, review and observation of all nonstructural components and systems.