CHAPTER 5: FACTORY BUILDINGS

SINGLE STORY REINFORCED CONCRETE COLUMN MILL BUILDINGS

235. The majority of the mill buildings at the Tangshan Rolling Stock Plant collapsed. (Photo: Li Yaodong)
236. The Coach Bogie Workshop of the Tangshan Rolling Stock Plant had steel roof trusses. The large roof plates fell down. (Photo: Earthquake Research Institute, State Seismological Bureau)

237. The Coach Body Workshop of the Tangshan Rolling Stock Plant had steel roof trusses. The well-type skylight windows were basically left intact but the roof plates fell down. (Photo: Xu Wei)
238. Roofs collapsed at the Cast Steel Workshop of the Tangshan Rolling Stock Plant. (Photo: Earthquake Resistance Office of Ministry of Machinery Industry)

239. At the Cast Steel Workshop of the Tangshan Metallurgical Mining Machinery Plant, many roofs collapsed but the roof trusses did not collapse where the roof braces were fairly perfect. (Photo: Yang Songlin)
240. The First Metal Working Workshop of the Tangshan Metallurgical Mining Machinery Plant consisted of mill buildings of different heights. The joints of the roof trusses with higher spans and column caps were damaged and roofs collapsed. (Photo: Yang Songline)

241. The Second Metal Working Workshop of the Tangshan Metallurgical Mining Machinery Plant had reinforced concrete columns and steel roof trusses. The gable wall of the main span collapsed and one end of the roof collapsed. (Photo: Yang Songlin)
242. The Fourth Metal Working Workshop of the Tangshan Metallurgical Mining Machinery Plant consisted of buildings of different heights. The joints of the roof trusses and column caps were damaged and roofs collapsed. (Photo: Han Jiagu)

243. A roof truss at the vertical brace of a skylight window frame was damaged at the Tangshan Metallurgical Mining Machinery Plant. (Photo: Zhang Xiquang)
244. At the Cast Steel Workshop of the Tangshan Metallurgical Mining Machinery Plant, the majority of the roof system collapsed but the trussed columns were basically left intact. (Photo: Yang Wenzhong)

245a. At the Metal Working Workshop of the Tangshan Cement Machinery Plant, roofs collapsed and short columns broke. (Photo: Xu Hanbo)
245b. At the Metal Working Workshop of the Tangshan Cement Machinery Plant, roof trusses of pre-cast spans collapsed and a roof plate fell through and hung on the short columns. (Photo: Xu Hanbo)

246. The Weaving Department of the Huaxin Textile Factory in the city of Tangshan had a saw tooth shaped roof. The top of the column at the end portion cracked and the roof collapsed. (Photo: Yang Wenzhong).
247. At the Assembly Workshop of the Tangshan Water Pump Plant the shear bracing at the end span was deformed and the tie buckled. (Photo: Chen Dasheng)

248. The roof collapsed at the Production Workshop of the Tangshan Water Pump Plant. (Photo: Chen Dasheng)
249. The upper columns failed and the roof partly collapsed at the Oxygen Refinery of the Tangshan Iron and Steel Company. (Photo: Zhang Xiguang)

250. The roof partly collapsed at the Oxygen Refinery of the Tangshan Iron and Steel Company. (Photo: Yu Chuncheng)
251. The columns became brittle and cracked and the roof subsided at the Rolled Steel Plant of the Tangshan Iron and Steel Company. (Photo: Han Jiagu)

252. The frame of the skylight and the roof collapsed at the Dross Treatment Workshop of the Tangshan Iron and Steel Company. (Photo: Zhang Xiguang)
253. The roofs collapsed at the Sintering Workshop of the Tangshan Building Ceramic Plant. (Photo: Wang Zhongnan)

254. Roofs collapsed at the Steam Turbine Workshop of the Tangshan Power Plant. (Photo: Earthquake Research Institute, State Seismological Bureau)
255. Roofs collapsed at the Steam Turbine Workshop of the Douhe Power Plant. (Photo: Qi Yongquan)

256. The roofs collapsed except for one span at the Machinery Workshop of the Douhe Power Plant. (Photo: Wang Gongkang)
257. The skylight collapsed and the roofs partially collapsed at the Metal Processing Workshop of the Tianjin Engineering Machinery Plant. (Photo: Liao Shutang)

258. The frames of the skylight were broken off and collapsed at the Foundry Workshop of the Tianjin Engineering Machinery Plant. (Photo: Xu Wei)
259. The roofs collapsed at the Hull Shop of the Tianjin Xingang Shipyard. (Photo: Seismological Brigade, State Seismological Bureau)

260. Almost all the upper columns were broken off at the Cast Steel Workshop of the Tangshan Rolling Stock Plant. (Photo: Zhang Qihao)
261. The joint plates of the x-brace between columns had one pulled off and the other one buckled, at the outdoor span of the Fourth Rolling Mill of the Tangshan Iron and Steel Company. (Photo: Yu Chuncheng)

262a. The concrete at the column joints peeled off and cracked and the reinforcing bars were deformed at the pre-cast reinforced concrete frame, above the gully for unloading, at the Douhe Power Plant. (Photos: Wang Gongkang and Shi Guobin)
262b. A close-up view of the damage at the Douhe Power Plant.

263. The concrete at the joint of the pre-cast reinforced concrete column cracked and reinforcing bars were deformed at a water supply well at the Douhe Power Plant. (Photo: Shi Guobin).
264. Concrete at the joints of pre-cast concrete columns peeled off and cracked at a pump house at the Douhe Power Plant. (Photo: Shi Guobin)

265. The end joint of the roof frame was damaged at the Stamping Shop of the Tianjin Tractor Plant. (Photo: Shi Lulin)
266. The upper chord of the roof truss near the end joint was damaged at the Stamping Shop of the Tianjin Tractor Plant. (Photo: Dong Jincheng)

267. The side column cap broke off at the Machine Repair Shop of the Tianjin Engineering Machinery Plant. (Photo: Shi Lulin)
268. A slab of an I-shaped hollow column cracked (upper) and reinforcing bars at the foot of the column buckled (lower). (Photos: Lei Tongshun and Shi Lulin)
269. The roof beam at the lower span dislocated and concrete at the end cracked at the Founding Shop of the Tianjin Xingang Shipyard. (Photos: Earthquake Resistance Office of the Ministry of Machinery Industry)
270. There were diagonal cracks at the end of the reinforced concrete beam at Xiangang the tenth garage at Tianjin Tanggu. (Photo: Liao Shutang)

271a. A brace between columns buckled at the Hull Shop of the Tianjin Xingang Shipyard. (Photos: Lei Tongshun, Shi Lulin and Liao Shutang)
271b. Vertical cracks along the plate of a column at the Hull Shop.

271c. Cracks at the foot of a column at the Hull Shop.
272. The upper portion of the infill protective wall collapsed and the reinforced concrete ring beam fell down at the Forging and Pressing Shop of the Tangshan Metallurgical Mining Machinery Plant. (Photo: Yang Wenzhong)

273. The gable collapsed and the end span of the roof was suspended in midair at the Heat Treatment Shop of the Tangshan Metallurgical Mining Machinery Plant. (Photo: Yang Songlin)
274. The gable collapsed at the Gas Blower Shop in the new air shaft of the Tangshan Mine, Coal Mine Bureau of Kailuan. (Photo: Chen Dasheng)

275. The gable collapsed at the Forge Shop of the Tianjin Bicycle Plant. (Photo: Yang Wenzhong)
276. A large portion of a reinforced concrete wall slab basically remained intact (above), but there was some damage at the joints of the wall slab and column (below) at the Second Steel Mill of the Tangshan Iron and Steel Company. (Photo: Central Research Institute of Building and Construction, Ministry of Metallurgical Industry)
277. The gable and eaves of a wall collapsed at the Tangshan Water Pump Plant. (Photo: Chen Dasheng)

278. The gable was out of vertical at the Steam Turbine Shop of the Tangshan Power Plant. (Photo: Qi Yongquan)
279a. At the Water Pumping House of the Douhe Power Plant, the bottom is an open caisson of reinforced concrete and the upper portion is a frame structure with reinforced concrete columns. The gable and a portion of the parapet collapsed. (Photos: Qi Yongquan)

279b. A close-up view of the collapsed gable at the Water Pumping House.
280. The base wall between the windows and columns was damaged at the Watering Pump House. (Photo: Qi Yongquan)
281. A gable and the upper portion of the longitudinal wall collapsed at the Machine Repair Shop of the Jinggezhuang Coal Mine, Coal Mine Bureau of Kailuan. (Photo: Chen Dasheng)

282. A gable collapsed and the end of a span was destroyed at the Shaped Plate Shop of the Xiaoji Iron Plant in Fengnan County. (Photo: Dong Jincheng)
283. The wall was out of vertical at the Forge Shop of Tianjin, the First Machine Tool Plant. (Photo: Earthquake Resistance Office of the Ministry of Machinery Industry)

284. The gable collapsed and the wall was out of vertical at the Foundry Workshop of Tianjin, the First Machine Tool Plant. (Photo: Liao Shutang)
285. A gable partially collapsed at the Sand Treatment Shop of the Tianjin Heavy Machinery Plant. (Photo: Earthquake Resistance Office of the Ministry of Machinery Industry)

286. The upper portion of the longitudinal wall of a multi-span factory building with reinforced concrete columns collapsed at the Metal Assembly Shop of the Tianjin Engineering Machinery Plant. (Photo: Earthquake Resistance Office of the Ministry of Machinery Industry)
287. The wall along with the bond beam collapsed at the Chassis Shop of the Tianjin Tractor Plant. (Photo: Liao Shutang)

288. The upper wall of collapsed and five pieces of the low span steel frame of the roof broke at the New Foundry of the Tianjin Tractor Plant. (Photo: Shi Lulin)
289. Longitudinal and transverse walls cracked and a roll of drawings got squeezed in the crack in an office at the Metal Working Shop of the Tianjin Tractor Plant. (Photo: Dong Jincheng)

290. A large number of the sawtoothed gables collapsed at a factory building at the Wool Sorting Shop of the Tianjin Woolen Mill. (Photo: Xu Wei)
291. Reinforced concrete wind vents (their tops were welded) together with the jointed gable collapsed at the Bench-work Shop of the Tianjin Xingang Shipyard.
(Photo: Liao Shutang)

292. The reinforced concrete frame structure, the upper portion of the gable and a portion of the roof collapsed at the Forge Shop of the Tianjin Xinhe Shipyard.
(Photo: Institute of Geology, State Seismological Bureau)
293. The whole structure tilted, bearing reinforced concrete columns, sheet beams and gable collapsed at the Warehouse of Tanggu New Harbor in the city of Tianjin. (Photo: Institute of Geology, State Seismological Bureau)

294. The protective walls partially collapsed at the Production Shop of the Dagu Chemical Works in the city of Tianjin. (Photo: Han Guangzhu)
295. At the Metal Working Shop of Tianjin, the First Machine Tool Plant, column supports which were strengthened before the earthquake cracked but did not fall down.
   (Photo: Liao Shutang)

296. At the beginning of 1976 at the Tianjin Generating Electricity Equipment Plant, gables were strengthened with steel bars and angle steel and were intact after the earthquake.
   (Photo: Li Yihong)
297. The joints between brick columns and concrete beams were strengthened by angle steel and bolts and were intact after the earthquake at the Tianjin Generating Electricity Equipment Plant. (Photo: Tianjin Building Design Institute)

298. The tops of gable walls remained intact at a tall mill, which was strengthened before the earthquake, at the Tianjin Generating Electricity Equipment Plant. (Photo: Information Center of the Tianjin Building Design Institute)
SINGLE STORY MILL BUILDINGS
WITH BRICK COLUMNS

299. The Spinning Department of the Huaxian Textile Mill in the city of Tangshan totally collapsed. (Photo: Earthquake Research Institute, State Seismological Bureau)
300. The bottom of the brick columns was damaged and the end span portions collapsed at the Locomotive Shop of the Tangshan Rolling Stock Plant. (Photo: Tong Maoling)

301. At the Tangshan Chemical Fertilizer Plant the gable wall and the end span of the roof collapsed. (Photo: Chen Dasheng)
302. At the Repair Shop of the Hebei Institute of Mining and Metallurgy in the city of Tangshan, the main span was slightly damaged and the bearing wall and the roof of the auxiliary span collapsed. (Photo: Central Research Institute of Building and Construction, Ministry of Metallurgical Industry)

303. The Calcine and Chomotte Shops of the Kailuan Guogezhuang Alumina Mine collapsed. (Photo: Coal Mine Bureau of Kailuan)
304. The Repair Plant of the Majiagou Mine, Coal Mine Bureau of Kailuan had bearing brick walls and brick columns. One side of the wall and columns broke at the elevation of windowsill, a crane beam collapsed and one side of the light roof fell down with it. (Photo: Sun Ming)

305. A warehouse with brick column bearings collapsed at the Tianjin Chemical Works. (Photo: Liao Shutang)
306. Brick columns broke at the crane beam level at the Belt Conveyor Shop of the Tangshan Metallurgical Mining Machinery Plant. (Photo: Earthquake Resistance Office, Ministry of Machinery Industry)

307. Brick columns at the diagonal brace cracked at the End Product Warehouse of the Qixin Cement Plant. (Photo: Chen Dasheng)
308. The light roof structure and a brick column were damaged at the Air Compressor Shop of the Tangshan Iron and Steel Company. (Photo: Central Research Institute of Building and Construction, Ministry of Metallurgical Industry)

309. The bottom of the columns at a metal material shed was damaged at the Majiagou Mine, Coal Mine Bureau of Kailuan. (Photo: Earthquake Resistance Group of the Design Administration Bureau, Ministry of Coal Industry)
310. The bottom of the columns were damaged at the Vertical Miller Shop of the Tianjin Xinhe Shipyard. (Photo: Dong Jincheng)

311. The brick columns below the windowsills collapsed at the Tianjin Xinhe Shipyard. (Photo: Liao Jishan)
312. Brick columns were damaged at a warehouse at the Ethylene Chloride Monomer Pitcher of the Dagu Chemical Works in the city of Tianjin. (Photo: The Sixth Design Institute, Ministry of Chemical Industry)
313a. The powdering building of the Tangshan Flour Mill was a 5-story poured-in-place frame structure which basically remained intact. The wheat barn to the right of the building was a 5-story brick masonry structure. The top floor collapsed and the brick columns on the bottom floor were broken off, seated in the initial place and tilted. This was caused by bearing capacity failure likely associated with liquefaction. (Photos: Hei Deyong and Institute of Geology, State Seismological Bureau)
313b. Back view of the powdering building and wheat barn.
314. The projecting portion of the top floor collapsed at the Winnowing Coal Dust Shop of the Jixin Cement Plant in the city of Tangshan. (Photo: Chen Dasheng)

315. The limestone vibrating screening building of the Tangshan Iron and Steel Company was a 4-story poured-in-place frame structure. The columns on the second floor broke off and the third and fourth floors settled down onto the first floor. (Photo: Central Research Institute of Building and Construction, Ministry of Metallurgical Industry)
316. A full view of damage of the main mill building at the Douhe Power Plant. (Photo: Shi Goubin)

317. The light roof plate collapsed at the Douhe Power Plant. (Photo: Qi Yongquan)
318. The fifth floor toppled down at a pre-cast 5-story frame structure between the Deoxidizing Shop and Coal Bunker at the Douhe Power Plant. (Photo: Shi Goubin)
319. Portions of the upper posts were broken off at the Turbo Generator Shop of the Douhe Power Plant which was a pre-cast frame structure. (Photo: Wang Gongkang)

320. The frame columns broke off and collapsed at the Deoxidizing Shop and Coal Bunker at the Douhe Power Plant. (Photo: Shi Guobin)
321. Poured-in-place reinforced concrete coal bunker at an elevation of 30 m fell down to an elevation of 8 m at the Douhe Power Plant. (Photo: Wang Gongkang)

322. The frame structure was seriously damaged and the protective brick walls collapsed at the Turbo Generator Shop of the Douhe Power Plant. (Photo: Shi Guobin)
323. There were cracks at the joint between the longitudinal pre-cast frame beam and column at the Douhe Power Plant. (Photo: Wang Gongkang)

324. The end column of the assembly frame was shattered. The main reinforcing bars deformed and hoop reinforcements were broken at the Douhe Power Plant. (Photo: Shi Guobin)
The majority of the in-fill walls collapsed at the coal crusher room at the Douhe Power Plant. (Photo: Shi Guobin)
326. The in-fill wall was damaged at the Deoxidizing Shop and Coal Bunker at the Douhe Power Plant. (Photo: Shi Guobin)

327. The in-fill wall was damaged at the main mill building of the Douhe Power Plant. (Photo: Shi Guobin)
An acetylene station at the Kaiping Chemical Works in the city of Tangshan was a 4-story frame poured-in-place structure. The joints between the beam and column were seriously damaged.  (Photo: The Sixth Design Institute, Ministry of Chemical Industry)
329. The Mirabilite Shop of the Kaiping Synthetic Chemical Plant in the city of Tangshan was a poured-in-place 4-story frame structure with filled walls. The columns of the third floor broke, the fourth floor fell to the third floor and was displaced to the north. (Photo: Seismological Brigade, State Seismological Bureau)

330. The beams of the frame broke at the synthetic tower at the Guye Chemical Fertilizer Plant. (Photo: Zhan Xinxin and Bai Chungzhang)
331. At the Guye Chemical Fertilizer Plant the top floor of the frame structure was brick. After the earthquake the brick masonry at the top floor collapsed and the poured-in-place roof was destroyed. (Photo: The Sixth Design Institute, Ministry of Chemical Industry)

332a. There were brick walls on the top floor and an open story at the bottom floor at the dress-room building of the Linxi Coal Mine, Coal Mine Bureau of Kailuan. After the earthquake the column caps of the bottom story were damaged. (Photos: Yang Derong)
332b. A close-up view of a damaged column cap at the dress-room building.

333a. The pithead room of the Fangezhuang main pit, Coal Mine Bureau of Kailuan was a 5-story poured-in-place frame structure. The skip store house located at the top collapsed. (Photos: Earthquake Resistant Group of Design Administration Bureau, Ministry of Coal Industry and Coal Mine Bureau of Kailuan)
333b. A full view of the collapse at the Fangezhuang main pit.

334. The shaft at the Coal-Dressing Shop at the Zhaogezhuang Mine 406 inclined. At the time of the earthquake the third floor was under construction; the shutterings on the second floor were not removed; and column caps were sheared and damaged. (Photo: Earthquake Resistance Group of Design Administration, Ministry of Coal Industry)
335. The frame structure was intact at the alumina material-supply system of Guogezhuang Alumina Mine, Coal Mine Bureau of Kailuan. (Photo: Zhang Xiguang)

336. The Titanium Chloride Workshop at the Tianjin Chemical Works had a reinforced concrete frame. The bottom story was slightly damaged and the brick masonry structure on the upper floor collapsed. (Photo: The Sixth Design Institute, Ministry of Chemical Industry)
337. The 666 Workshop at the Tianjin Chemical Works was originally a 4-story poured-in-place frame structure with a fifth story added later. The upper two stories were seriously damaged during the earthquake. (Photo: Information Station of Tianjin Building Design Institute)

338a. The Beicang Ceramics Warehouse of the Tianjin Handicraft Export and Import Company was a pre-cast 3-story frame structure with column capitals and tall columns. The front of the structure was basically intact. (Photos: Information Station of the Tianjin Building Design Institute)
338b. A joint between a beam and end column and gable wall was damaged at the Beicang Ceramics Warehouse.

338c. Frame columns were also damaged at the Beicang Ceramics Warehouse.
339. The corner column broke off at the middle south building of the Second Wool Mill in Tianjin. (Photo: Liao Shutang)

340. The steam absorption building of the Tianjin Caustic Soda Plant was a poured-in-place 13-story frame structure. The floors above the seventh floor collapsed. (Photo: Mao Shihong)