CHAPTER 6: EARTHQUAKE RELIEF AND RECONSTRUCTION OF TANGSHAN

DISASTER RELIEF AFTER THE TANGSHAN EARTHQUAKE

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The city of Tangshan, with a population of one million, was struck by the M7.8 earthquake at 4:00 a.m. on July 28, 1976. It is said in China that 243,000 people lost their lives. Most of the houses and buildings were destroyed; there was no electric power, no running water, no functioning sewers, no gas, no telephone communication, no functioning city government, no highway traffic or railway traffic into the city. In effect, at four o'clock the city ceased to exist leaving over 500,000 homeless survivors. The central government organized a massive relief and reconstruction program, and since the disaster was too great for the Province to cope with, other Provinces were called upon to contribute men and materials. Teams were dispatched to deal with emergency disaster relief and emergency repair of public utilities and industries; and complete reconstruction of the city was undertaken. This account of the disaster was written shortly after the earthquake. A more detailed account of relief and reconstruction has not been published.

More than 100,000 officers and soldiers of the PLA went to the disaster region from Beijing, Shenyang, Hebei and other areas. They played a central role during the emergency disaster relief (see Photo 1). Under the direct jurisdiction of the central government all the provinces and cities as well as the autonomous regions sent medical workers and specialized personnel from industry, communications, postal and telecommunication, construction, water and power supply, mining rescue, etc. to the disaster area. At the same time large quantities of medicine, grain, food, construction equipment and daily necessities were transported to the disaster area.

The CPC Committee of Hebei Province together with the Beijing Military Area Command, the Shenyang Military Area Command, and the United Work Group of the State Council set up a lead group and established the Headquarters of the Tangshan Earthquake Relief to direct the project. The army units taking part in the earthquake relief all set up special headquarters. Hebei Province also set up the Rear-Service Headquarters of Earthquake Relief to form an earthquake relief command system of the Party Committee of Hebei Province.

In this large-scale effort of earthquake relief, the Tangshan Earthquake Relief Headquarters managed many forces, organized rescues, provided temporary buildings, transported disaster relief material, provided living arrangements for survivors, launched protection against epidemic disease, handled public security and propaganda and education, restored industrial and agricultural production, etc.

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I. Rescue, Repair and Transportation

1. Rescuing people in collapsed buildings was the most urgent task in beginning the earthquake relief

The earthquake occurred at 4:00 a.m. and nearly all the houses and buildings in the city collapsed and approximately one million people were affected. Even those who worked the night shift did not escape death and injury.

After the earthquake members of various cadres organized cadres and the people who had escaped to assist in the rescue of victims. The leading cadres of the Kailuan Coal Mine first thought of the safety of 10,000 workers in the pits regardless of the casualties of their dependents. They organized the workers and cadres who had escaped the danger into pit rescue teams and opened all the spare vents to rescue their fellow workers in the pit. The cadres of all levels of the Kailuan Coal Mine and all of the subordinate mines organized workers to proceed with the rescue operation. The temporary Party Branch of the Lujiatuo pit put forward the requirement that the non-Party people were to be rescued first, Party members second; workers first, cadres second. The 10,000 workers in the pits of all the mines subordinate to the Kailuan Coal Mine mostly returned to the ground surface within several hours after the earthquake.

At the same time, an independent relief effort was undertaken in the city and countryside. Having few tools, people removed bricks and rubble with their hands and lifted heavy broken posts and beams to rescue victims.

Under the leadership of the Party organizations and with the cooperation of a large number of Party members and cadres the rescue work proceeded quickly. In the high earthquake intensity area most of the buried people were rescued the same day the earthquake occurred. Urban workers and citizens of Tangshan City and officers and men of the army stationed in Tangshan overcame one difficulty after another and rescued most of the people rapidly. All the barracks of a unit of the No. 66 Army collapsed completely during the earthquake and there were 1,800 people in the collapsed barracks. The army rapidly organized a self-relief effort and in a half an hour all the people were rescued. Afterwards they went to nearby places to rescue people. On the same day this unit dug out 5,572 buried people and 4,509 of them survived. On the second day the unit dug out 1,638 people of which 552 were survivors. On the third day 743 people were dug out by the unit and 103 were survivors. After the 5th day there were very few survivors. This indicated that the first 2 days, especially the first day of the earthquake, were very important for the rescue of survivors.

More than 110,000 officers and men from the Beijing Military Area Command, the Shenyang Military Area Command and construction engineer troops arrived at the disaster area. Putting forward the pledge "letting the people have hope for life and keeping danger of death for oneself," they climbed hazardous buildings and went through dangerous openings and rescued large numbers of people. In order to rescue those people still alive the officers and men of the PLA organized many detachments to search for victims and mobilized people to identify victims needing rescue. Army commanders organized army personnel, crane teams and also the medical teams from other parts of China. They rescued more than 16,400 people by working day and night.

With the lapse of time the rescue work became more and more difficult and people rescued alive became fewer with each passing day. However, the effort to rescue every possible live person was continued. "If there is 1% of hope, 100% of effort is made for the rescue". This was the slogan of the rescue workers of the PLA. On August 4, the 8th day after the earthquake, the officers and soldiers of the 9th Company heard a weak voice calling for help from the ruins of the Kailuan Hospital. They dug a trench 10 m long in the rubble and prized layers of collapsed floors and after 6 hours, along with the cooperation of the medical team; they finally rescued Wang Shubin who was a worker at the Tangshan Alumina Mine. When the officers and soldiers of the "All-Conquering Boshan Heroic Company" knew that there might be people in the west end of the first floor of the medical department in the collapsed Commercial Hospital they cooperated immediately with the engineer troops; they began to dig up the west end of the collapsed building. Finally, they dug a small hole 10 cm in diameter from which a woman's weak panting was heard. They were afraid of hurting the victim if they were to use power tools. Instead, they used their hands to remove the rubble and broken concrete. More than 10 soldiers carried away three pieces of concrete slabs each weighing more than one ton and they pulled down the shattered wall on the west side. On August 9 they finally rescued the woman, Lu Guilan; having been buried for 303 hours under the ruins. She was treated for 24 hours after she was pulled out with no serious injuries.

Chen Shuhai and four other miners of the Zhaogezhuang Mine in Kailuan stayed in the pit for 15 days. When the earthquake occurred they were working in the No. 10 tunnel, which was 900 m from the ground surface. The coal wall collapsed and the vertical shafts were blocked and they were stranded in the No. 059 work area. They experienced several setbacks but fought bravely for 50 hours and dug through the 16 m blockage. They walked out of the work area. The electricity was out so they felt for the electric cable, and holding hands they climbed against the wind for nearly 800 steps and arrived at the No. 8 tunnel. These five workers wanted to climb to the No. 7 tunnel but a stream of water blocked the way, so they rested in two mine cars. When they were thirsty and hungry they drank dirty water and nibbled the coal. When they were cold they huddled close together. They firmly believed that the Party organization would send people to rescue them. The Party Committee of Zhaogezhuang Mine was anxiously searching for these five workers and they were finally discovered on August 11, fourteen days after the earthquake. These five miners successfully returned to the surface after being given emergency treatment in the pit.

Forefront rescue, i.e. timely treatment and on the spot dressing of wounds for the large number of injured people and emergency treatment for the critically injured was the key link to reducing infection and death (see Photo 2). Since there were large numbers of injured people in Tangshan City it was an arduous task to treat them. The city medical workers and those in the industrial enterprises set up many temporary dressing and medical stations by the road or at the ruins. The 11 provinces and cities under the direct jurisdiction of the central government (Beijing, Tianjin, Shanghai, Heilongjiang, Jilin, Liaoning, Shanxi, Shandong, He'nan, Hubei and Jiangsu) and the rescue troops of the PLA sent 283 medical teams and nearly 2,000 medical workers in total to the disaster area (there were 134 medical teams and 8,900 medical workers in Tangshan). They worked day and night and they did their best to rescue the victims.

2. Repairing communication, traffic, electrical power and water supply equipment

After the occurrence of the earthquake Wu Dongliang, a radio operator in a unit of the PLA, rushed to get the radio station operating and at 4:03 a.m. got contact with the radio station of a higher command. The Tangshan Airport reported to the capital of China using a short-wave radio in a plane. It was very important that the Tangshan Airport could be used for planes to take off and land. The leading comrades of the Party Committee of Hebei Province rushed to Tangshan and set up a radio station. At 1:20 p.m. they got in contact with the Party Central Committee. Tangshan City and Tangshan Prefecture personnel worked in cooperation with more than 1,200 people from postal and telecommunication departments from 9 provinces. They put through the first trunk-line and got through to Shijiazhuang at 1:20 p.m. and began sending and receiving cables. At 7:20 p.m. the next day, with the help of the Postal and Telecommunication Bureau of Tianjin City, a 12-channel carrier was set up at the outskirts station and direct lines from Tangshan to Beijing, Tianjin, Shijiazhuang and Shenyang were operating. By July 31, telephone communication was restored with 400 lines to counties and communes in the Tangshan Prefecture.

After the earthquake large quantities of disaster relief materials were needed and had to be transported to the disaster area and large numbers of injured people were waiting to be taken to other parts of the country for treatment. Unfortunately, the railways in Jingshan, Tongtuo and Tangzun, etc. were seriously damaged and the main highways of Tangqin, Tangbo, Jintang, etc. which led to Tangshan were disrupted by cracking, subsidence and some were covered with water and sand. The major bridges on these main highways such as the Luanhe Big Bridge, the Shahe Bridge, and the Tangshan Shengli Bridge were damaged by the earthquake and were impassable therefore, rapid repair of highways and railways needed to be done in order to quickly restore transportation.

Repairing the highways was divided into two stages. The first stage was to determine the damage and to plan the repair and immediately prepare temporary routes for automobiles. The first thing was to organize forces to quickly repair main highways to open them to traffic. The Headquarters of the Tangshan Earthquake Relief organized 4,500 people in total from the No. 3 section, the No. 1 Bureau of the Ministry of Communications, the Communications Engineering Brigade of Hebei Province and some from the prefecture engineering teams to repair key bridges and seriously damaged main highways. Twenty-eight thousand officers and soldiers of the PLA erected temporary boat bridges and began to repair highways. The local highway management departments organized 15,000 people to repair the surface of the highways and erect simple wood bridges. By August 10, highway transportation in the Tangshan Prefecture was in operation. In mid-August the second stage to restore the highway system to pre-earthquake conditions began.

At the same time the highways were being repaired the railways were also being repaired. Forty-two thousand three hundred people of 28 units from the Railway Bureau, the Engineering Bureau and Railway Troops took part in the emergency repair of railways. Abiding by the principles to open the railways to traffic first and completely restoring them second, and to repair the main lines first and branch and special lines second, they did their best to open the railways to traffic. The railways in Jingshan and Tongtuo were the main railway lines connecting Northeast China, North China and Beijing. The restoration of transport played a very important

role in relocating victims in the disaster area and in restoring manufacture and rebuilding Tangshan. For example, the No. 12 Company of a unit of the Railway Troops was repairing the lift tower for the boat bridge and 25 officers and men went underwater to clear the mud and to lay flat foundation stones. They worked continuously for 18 hours. On August 3, the Tongtuo railway line was repaired and became open to traffic. On August 7, the single-track line of the Jingshan Railway was opened to traffic. On August 10, the twin-track line was opened to traffic and 7,600 casualties were transported out of Tangshan and goods and materials were transported in. On September 28, the passenger trains of all railway lines were in operation. Up until the end of October they had repaired 897 km of main lines and station lines, 146 branch and special lines totaling 413 km, repaired 63 bridges, built temporary buildings and repaired 330,000 m^2 of housing. The capacity of the railways essentially reached the pre-earthquake level.

The emergency repair of the electric power supply system was conducted under the direct command of the Electrical Power Industry Control Bureau of Beijing under the Ministry of Electrical Power and Water Conservancy. On the day the earthquake occurred it mobilized more than 3,000 people from the power departments of Beijing, Tianjin, and Tangshan. Uniting and cooperating with the workers and staff of the Beijing Power Control Bureau and the Power Bureau of Hebei Province, they transported two power generators to the disaster area on the day the earthquake occurred. That night power was supplied to the Tangshan Earthquake Relief Headquarters. On the second day after the earthquake the power transmission line from Yutian to Tangshan was repaired and power from Beijing was transmitted to Tangshan. On the third day after the earthquake the urban water supply locations, the airport, streetlights and the Kailuan Mine were supplied with power. The power supply range became continuously larger with the gradual restoration of power transmission and substation systems and restoration of power generation at the Tangshan Power Plant. The 220,000 V Douhan power line, which had generally been completed in construction but not yet put into operation, was quickly repaired. This increased the power supply and the need for power in the Tangshan disaster area was met on a temporary basis.

Repairing water supply installations was another key element in the repair project. After the earthquake water installations were seriously damaged: the pump rooms collapsed, equipment was smashed, pipe networks broke, and all the water supply was stopped. The supply of drinking water for the people was provided by sending water wagons and fire engines. After this the repair of running water installations was organized. The repair team of Shijiazhuang City was the first to arrive in Tangshan by airplane and the repair teams of Zhangjiakou, Baoding, Handan, Qinhuangdao, Chengde and Yingkou, etc., arrived in Tangshan one after another. The Running Water Corporation of Tianjin City, in spite of suffering damage from the earthquake sent equipment and pipe material that was urgently needed. The State General Material Bureau airlifted 15,000 m of hose and 40 tons of steel pipes. The water supply depended on the water sources and the water transmission therefore, water sources were repaired first. When one well was repaired it was put into operation at once. Serious damage to the pipe network was first repaired then local damage to pipes was located, closing valves on the branch pipelines and forcing the water through the main pipelines aided in locating and repairing leaks. Once the main pipelines were in operation the branch pipelines were gradually restored. They were restored from one branch pipeline to a large group of lines and they were finally connected to form a network. During the time when water could not be supplied by a unified system, each

source well or water station was used separately to supply water to a local district. Temporary pipes and faucets were used to provide water to various regions. Water faucets were set up in places where they could be reached conveniently by the people. When the wells and water stations were operating and the main pipes in each district were put into operation and all the main pipes were connected the unified water supply was restored to pre-earthquake condition. By October 10, 39 wells had been restored to operation, 9 secondary pressure pumps had been restored and installed, 166 km of main pipeline had been restored, 510 large pipe leaks and nearly 1,000 small pipe leaks had been repaired, 528 public water faucets had been restored and 58 water faucets were set up to restore the water supply capacity to the level before the earthquake.

3. Importing disaster relief material and transferring injured people to other areas in China

The Air Force of the PLA and the departments of railway and highway launched a major effort in order to transport several hundred thousand earthquake relief personnel and large quantities of disaster relief material from all sides to the disaster area and to transport large numbers of wounded people to other parts of China for treatment.

In the beginning airlifts were mainly used to transport material and to evacuate seriously injured people to other parts of China. The Tangshan Military Airport communication was seriously damaged which included the radar navigation equipment. The air traffic controllers listened for the sound of an airplane and visually directed the airplane to land safely. The airplanes carrying injured persons took off one after another and the airplanes carrying disaster relief material and support personnel flew in from more than 20 airports in the country and landed in Tangshan one after another. Sometimes in the airspace of the airport several different types of airplanes appeared at the same time and demanded to land simultaneously. Controlling the airplanes to the proper altitude and to different take-off and landing routes and conducting temporary deployment of airplanes in the air the air traffic controllers safely directed the airplanes to land one by one. Double-direction take-offs and landings on the right and left runways were used for greater efficiency. Six days after the earthquake 1,364 sorties had taken off and landed; the maximum was 350 in one day. The maximum frequency was controlled by an interval of only 26 seconds between planes.

In the beginning ground transportation mainly relied on automobiles. The Headquarters assembled more than 1,200 automobiles in the province, which were organized into more than 10 disaster relief automobile teams. The central government also allocated more than 2,400 automobiles to the disaster area. The General Transportation Corporation of the Ministry of Communications, the Communications Bureau of Beijing, and the transportation departments of the prefectures of Fushun and Yingkou also sent automobiles for assistance. At that time the number of motor-driven vehicles from all the disaster relief contingents was over 8,000. In addition to the locally driven motor vehicles the vehicles entering and leaving Tangshan City daily were over 20,000. Before the earthquake the number of daily motor vehicles on Tangfeng Highway was less than 3,000 and after the earthquake it was up to 9,000. The number of daily motor vehicles on the section of Yutian to Tangshan on Jingshan Highway was less than 2,000 and after the earthquake it was up to 8,000. The number of vehicles sharply increased even though the highways were damaged. The streets and lanes in Tangshan were blocked by

collapsed buildings, slightly injured and seriously injured people, and people getting out of danger by putting up tents and sleeping in the open. Corpses of people killed in the earthquake were put along the streets. A large number of vehicles transporting disaster relief material were in Tangshan so there were very serious traffic jams in Tangshan City for two to three days after the earthquake, and it often took four to five hours for an automobile to pass through the city. To counter this problem communication control was implemented and troops were sent to provide information and help people clear the streets and open the roads. The main streets were identified and one-way roads were established. Unnecessary vehicles were not allowed to enter into the city. At the same time a combination of army men, militiamen and traffic policemen were adopted to direct and control traffic. The PLA sent more than 400 officers and men to take part in traffic control. Beijing and Shijiazhuang, Zhangjiakou, Handan, Chengde, Xingtai and Cangzhou in Hebei Province also transferred some of their traffic policemen to Tangshan for assistance. Road signs were put up at main traffic crossings and the traffic jam situation changed rapidly. By July 31 the main streets and several main roads had been unblocked. For traffic efficiency all the local vehicles were commandeered and controlled by the communications group of the Headquarters. Workers and staff members accomplished much and a large quantity of material was transported to Tangshan from all parts of China after the earthquake. By the end of October 474 sorties had been used to transfer 20,700 wounded people to other parts of China. In railway transportation 159 special trains had been used to transfer 72,800 injured people; these people were transferred to hospitals in 9 provinces in Jilin, Liaoning, Shandong, Shanxi, Hubei and those in Shijiazhuang, etc., of Hebei Province. Special lead groups were set up in these provinces and prefectures. Of the 90,000 seriously injured people only 913 people died.

In order to coordinate railway and highway transportation and the receiving, unloading and distribution of material, receiving stations were set up one after another at the 8 railway stations around Tangshan City. Later, 10 more material receiving stations were set up along the railways. All the material transfer stations were jointly composed of people transferred from troops and departments of finance, commerce, material, communications, railway, etc. and they were equipped with automobiles to load and unload workers and equipment. They were not only in charge of loading and unloading material but also in charge of distributiing and transporting the material rapidly and orderly.

II. Living Arrangements for the People

The strong earthquake brought extreme difficulties to people who lived in the earthquake disaster area. It was most difficult in Tangshan City since it was in the epicentral area. Buildings collapsed, water and power supply were cut off, food was buried and cooking utensils were smashed. Since the earthquake occurred before dawn most of the people were not dressed. Therefore, it was of great significance to let the people have water to drink, food to eat, clothes to wear, and houses to live in, in order to stabilize their spirits and to launch earthquake relief.

It was a scorching summer and people could not stand their terrible thirst. The people who escaped danger were threatened first by the cut-off of the supply of drinking water. When workers in Beijing got this information they refitted 30 water tank vehicles and filled them with clean water and traveled 250 km to transport water to Tangshan. The countries near Tangshan City used all means available such as automobiles, carts, large handcarts, water cabinets, rubber

carts, etc., to transport water to Tangshan. In Tangshan City several temporary emergency measures were adopted. The first was to utilize the 6,000 tons of water in the water distribution stations and water storage ponds and to supply the water to people in a planned way. The second was to make use of the more than 30 wells in the city proper. They equipped them with power to provide water to people on the spot. The third was to organize fire engines, watering cars and oil cars provided by the entire country to supply water to appointed households. The fourth was to use pressure-replenishing wells in the city proper to lay hoses all around and form a large number of temporary water supply locations. On this basis a mass campaign for repairing running water installations was conducted to make the water supply gradually shift to a normal situation.

In order to solve the problem of eating all the cities and prefectures in Hebei Province cooked day and night and prepared food such as pancakes, steamed breads and biscuits, etc. For example, the Eating Corporation in Shijiazhuang City was assigned the task of processing 5,000 kg of prepared food at zero hour on July 30; they immediately mobilized 339 workers and staff members from 35 sales departments. They started the processing equipment and processed 6,090 kg of prepared food in only 5 hours. The food was then transported to the disaster area. People from quite a number of prefectures and cities offered to undertake the task of preparing food for the disaster area. The citizens of Longyao County of Xingtai Prefecture, which suffered from an earthquake disaster in 1966, took into consideration that the disaster area was short of water so they didn't put salt into the pancakes. Instead they transferred all the sugar stored in the entire county and cooked sweet pancakes and transported them to Tangshan. Beijing and some other provinces and cities under the direct jurisdiction of the central government also transported large quantities of food such as biscuits and bread, etc., to the disaster area. A total of 4.87 million kg of prepared food was transported to the disaster area. During the first few days after the earthquake nearly 100 sorties were flown daily to airdrop food to the worst disaster area. Then, the method was changed so that the PLA distributed food to the affected people. While the prepared food was being supplied 75 million kg of processed grain was transferred to the disaster area. The workers and staff members in the field of finance and commerce tried to restore the production and processing of grain and edible oil as well as non-staple foods. Originally there were 108 grain supply stations in Tangshan and they all restored business by the middle of August. By the end of October they produced 23 million kg of grain monthly; close to the level of 25.5 million kg before the earthquake.

Restoring the business network and stations to supply commodities was actively done. The commercial organizations of various levels in Tangshan City were seriously damaged, so in the case that wages were not paid out in August a free and rationing supply method was used for the people's necessities of life such as grain, vegetables, edible oil, pork, salt, pickles, soda, soap, kerosene, matches, and women's sanitary napkins, 11 varieties in total. In accordance with actual needs part of the cooking utensils, clothes, shoes and socks were distributed. People in the disaster area said with deep feeling, "In the old society, when a disaster occurred the local authorities and profiteers took advantage of the people's misfortune and the laboring people became destitute and homeless. Today, in a socialist society the Party and government have showed the utmost solicitude to the people in the disaster area. We have been hit by a natural disaster but we are not in distress. The old and new societies are really two different worlds." The implementation of this type of supply system could only supply the main necessities of life

though people's needs were many. Therefore, to rapidly restore business networks and shops to make life move towards normal was important to encourage the people. In the restoration of business networks and shops the policies of self reliance, using local materials, setting up small shops and building more comprehensive ones were implemented. The workers and staff members in the field of finance and commerce were eager to help the people and supply them with what they needed, overcoming one difficulty after another. They were determined to dig out the buried commodities, to rebuild the stores, and restore the supply. Zhenxing Store, which was open for business on the 7th day after the earthquake was the first to open in Tangshan City. At the Xinshiqu Department Store the workers and staff members did the jobs of setting up buildings, checking the warehouses and arranging commodities. They first set up mat sheds to sell goods; with the help of the PLA they set up a semi-permanent store. On September 14 they opened for business and managed over 4,800 varieties of commodities with a daily sale volume of over 30,000 yuan, close to the level before the earthquake. Then, more "Zhenxing" type stores of general merchandise sold food, hardware, communication and electrical products, non-staple foods, vegetables, etc. Up until the end of December 520 stores which accounted for 74% of those before the earthquake were restored. More than 50 commission stations and mobile vending stations were restored and set up, which generally guaranteed the supply of daily used articles. In addition, the business banks and savings banks were restored to deal with various kinds of business. In order to accommodate people from other parts of China who came to help Tangshan, the restoration of restaurants and hotels was of high priority and the business done was soon up to 92.9 % of that before the earthquake.

To help people solve the problem of lodging before winter came was a very urgent task. On August 6, the Earthquake Relief Headquarters of Tangshan held a meeting about building houses and put forward the policy of mobilizing the people and using local material, doing things simply and thriftily and gradually completing the work. A mass movement to build houses through general mobilization and the pitching in of the army and people was formed in Tangshan Prefecture. Many provinces and cities under the direct jurisdiction of the central government transported large quantities of building material for houses, in which included 38 million pieces of mixed wood boards, over 0.9 million rolls of asphalt, and 1.38 million pieces of reed mat. With the assistance of the PLA the vast number of people helped each other with mutual support. Up until the end of October 379,000 temporary rooms had been built in Tangshan City and 1.57 million temporary rooms had been built in counties in the prefecture. In general, each household had one to two rooms. These simple rooms generally met the requirements of being earthquake-proof, rainproof, and fireproof. Before winter came cotton-padded clothes and quilts with cotton batting were granted to households, which were short of clothes and quilts. At the same time, arrangements for coal used for cooking and heating were also being conducted.

Solving the preliminary problems of eating, drinking, clothing, living, paying wages, paying the injured workers and staff members, comforting and compensating the dependents of those killed and solving the problem of relief became important in the economic life of workers and staff members. As a result, a special group was organized to conduct interrogations, listen to different opinions and refer to the "Regulations of Labor Insurance" and other regulations concerned and as a result the following principles were determined.

Concerning pay for the injured people and the comfort, compensation and relief for dependents of killed workers and staff members, first the conditions of being on duty or being

off duty was distinguished and treated differently. All those who were killed or injured while carrying out the tasks of their posts and those who rushed to deal with the emergency and provided disaster relief were treated as on duty casualties. Others were treated as off duty casualties. For those who were injured and became disabled while on or off duty the "Implementation Details of Labor Insurance Regulations (revised draft)" or other regulations were implemented. For the direct dependents of workers and staff members killed on duty, those whose income combined with the comfort and compensation fees exceeded the local general living standard were paid monthly with comfort and compensation fees in accordance with the regulations concerned in the "Labor Insurance Regulations". Those whose income combined with the comfort and compensation fees, which were to be granted, did not reach the local general living standard were given monthly subsidies in accordance with the general living standards. For the direct dependents of workers and staff members who were killed while off duty, those whose income reached or exceeded the local general living standard were granted a one time relief payment and those whose income did not reach the local general living standard were granted monthly general living subsidies.

The earthquake disaster made over 7,100 aged persons and children become solitary old men or women and orphans. After the earthquake over 760 children were transferred to the cities of Shijiazhuang, Xingtal and Cangzhou to be raised temporarily. With the rescue work underway, retirement homes and kindergarten homes in the city and countryside were set up. Means of recuperation for amputated and paralyzed people were provided.

Restoration of cultural and educational activities was also undertaken. A large number of teachers, students, administrative personnel and workers neither waited for, nor relied on, help. They restored classes first and built schools second despite the fact that there were casualties and that school buildings and teaching equipment were damaged. By the middle of August nearly 100 primary and middle schools in Tangshan City had restored classes. The Tangshan Mine and Metallurgy College suffered the most serious losses. The buildings covering an area of over 72,000 m^2 all collapsed and all the teaching materials were smashed. Nearly half of the teachers were killed or were seriously wounded and became disabled.[2] The teachers, students, administrative personnel and workers rapidly built more than 830 classrooms with the help of the PLA. They dug out and cleaned teaching materials and production equipment and provided for the restoration of classes and enrollment of students. Since many teachers not only taught their lessons but also lectured on other subjects, the college hired additional teachers to replace them so the college could restore classes in 11 specialties during the first 10-day period in September. Many literary and art workers buried the remains of family members and fellow comrades. They created and performed a large number of small literary and art programs, which improved the morale of the people. Film workers went deep into the factories, mines, and villages and projected films at night in open air. At the first Spring Festival after the earthquake 27 specialized literary and art organizations and over 6,100 amateur performance teams took part in performing activities. Over 130,000 performances were conducted. These enlivened the cultural life of the city and the countryside.

[2] If the same ratio is applied to the city it indicates that approximately 500,000 were killed or permanently disabled.

III. Preventing Epidemics after the Earthquake

People in the disaster area were seriously threatened by epidemic diseases.

Chinese history records indicate many occurrences of pestilence after an earthquake disaster. In January 1556, a great earthquake occurred in Shanxi Province and 100,000 people died at that time. During the following year pestilence occurred and 700,000 people died. The number of people who died of pestilence was seven times that of people who died from the earthquake. In 1949 an earthquake of magnitude 6.3 occurred in Luanxian County in Tangshan Prefecture. Not many people in Xinglongzhuang Village, the epicenter of the earthquake, died but epidemic disease occurred in the summer and autumn of the following year. In only a few days more than 100 people died. "There must be a big pestilence after the occurrence of a great earthquake" had long been believed by the people.

The Tangshan earthquake occurred in midsummer. It was hot, cloudy and drizzly for days on end. The remains of dead people and livestock began to rot and smell. Simultaneously toilets collapsed and sewage pipes were blocked, excrement, urine and garbage accumulated, drinking water was seriously polluted and mosquitoes and flies grew in large numbers. The people in the city proper drank water from swimming pools and bathing pools as well as from puddles. The number of colon bacillus in the drinking water exceeded state health standards by several tens, several hundreds, several thousands or nearly ten thousand times. In some places the average density was 400-500 flies to 1 m^2 of excrement and urine. In places near the cultural palace the density was 1,000 flies to 1 m^2 of excrement and urine. Flies in accumulated garbage and grassland around the downtown Xiaoshan area were a dense crowd that could not be calculated. In 1 m^2 of accumulated garbage 300-400 fly maggots grew in average per hour. Each kg of garbage soil contained 450 maggots. Large numbers of patients suffering from enteritis and dysentery appeared on the 3rd and 4th days after the earthquake. The number of patients reached the highest in about a week. After several days the second highest number appeared. The sickness rate in the city proper was as high as 10%-20% and that in the countryside was as high as 20%-30%. People in the disaster area were seriously threatened by epidemic disease. Handling the epidemic quickly was of great importance.

1. Actions taken to protect public health

During the earthquake large numbers of people were killed. The remains of the dead soon became putrefied. This not only made the flies grow, but also caused the spread of epidemic diseases and greatly affected the people's morale. The Earthquake Relief Headquarters of Hebei Province undertook the large-scale work of cleaning up remains while it organized the rescue of people buried under collapsed houses. It demanded that the remains be interred in 8 deep-buried cemeteries, which were 5 km away from the city proper. The buried depth was more than 1 m. The PLA undertook this very strenuous task. The officers and men worked day and night to complete the task of cleaning up the remains. The epidemic prevention teams and medical teams cooperated closely and they spread bleaching powder where the PLA went to clean up the corpses.

After the earthquake a large number of remains were buried in the city proper or in the city suburbs. Whether this could cause the spread of epidemic diseases or not, or whether this could pollute the soil, grains, and vegetables or not were questions the people were universally

concerned about. At that time many were fearful of the remains. The Hebei Medical College, the Hebei Health and Epidemic Prevention Station, the Hebei Medical Science Research Institute and Soil Quality Protection Research Institute and the Research Group of Remains Cleaning and Epidemic Prevention were composed of people from the two cities of Tangshan and Qinhuangdao. They collected 394 samples of air and ground water around the remains and the pits. Tangshan's running water and the cabbage and turnip vegetable fields, which had the remains, buried underneath were tested and analyzed using various methods. The results did not show the pathogenic bacteria that caused intestinal diseases such as typhoid, dysentery and cholera, etc., thus, the people's concerns were minimized.

The pollution of water sources after the earthquake was the main channel for spreading infectious intestinal diseases. The sterilization of drinking water wells was an effective measure taken in preventing infectious diseases from spreading. As soon as the epidemic prevention teams arrived at the disaster area they sterilized the drinking water. The fixed water sources were all guarded by the PLA and militias. The health workers sterilized them at fixed hours. All the water carts were followed by health workers and they sterilized them one by one. Some health workers went from streets to lanes and entered the tents and sterilized the water in the vats and barrels household by household. In the countryside of the disaster area the simple running water installations and motor-pumped wells which were damaged by the earthquake were restored. Wells with large openings were cleaned out. After many tests and chemical examinations most of the water qualities conformed to the state health standard.

Flies and mosquitoes were the main mediums for spreading epidemic diseases. The mass movement to wipe out flies and mosquitoes with pesticides was launched in large scale to reduce their numbers and prevent epidemic diseases from spreading while water sources were being sterilized. The Party Central Committee and the State Council gave orders to transfer 4 airplanes to the disaster area to wipe out insects. On August 9, 16, 23 and on September 5 (each spraying lasted 2-3 days) airplanes sprayed pesticides on Tangshan City proper, the suburbs, the East Mining District and on Fengnan County 4 times in succession. The airplanes operated 95 sorties and the spraying covered an area of 25,000 mu. The airplanes operated 46 hedgehopping sorties and the spraying covered an area of 399,000 mu. In total, 45.29 tons of low-poison organic phosphorous pesticides were sprayed. According to observation of 10 spots on Fuxing Road, Lunan District, and Tangshan City, half an hour after the pesticides were sprayed the density of flies was reduced by 84% in average and in some spots the density was reduced by 95%. The effect on mosquito density was also very obvious. In addition to airplane spraying 31 pesticide sprinklers, 1,900 various kinds of sprayers, 50,000 small household sprayers and several hundred tons of pesticides were used.

Medical teams and epidemic prevention teams in cooperation with local medical workers isolated and treated those who suffered from infectious diseases.

2. Mastering the spread of infectious diseases after the earthquake

When September came, though the incidence of various infectious diseases was controlled to the level of a normal year, the sanitary conditions of living and the environment for the people were still very poor. The tents, shacks and simple houses were low and crowded. The sanitary installations in the city and countryside were seriously damaged and they could not be restored

in such a short period of time. After the earthquake large quantities of excrement and urine and garbage accumulated. This accumulated filth tended to pollute water sources. The spread of infectious diseases of the respiratory tract and intestine, especially encephalitis B and malaria was a threat.

The epidemic prevention teams and the health departments of the city and prefecture held many meetings and had discussions with experienced doctors from the departments of infectious diseases, internal medicine, and pediatrics. They also visited medical personnel, both western medicine and traditional Chinese medicine, and investigated historical data about the incidence of various infectious diseases and the rate of spreading in the city and countryside. They found that 18 types of infectious diseases had occurred in Tangshan Prefecture since 1949. The five most serious were influenza, epidemic encephalitis, dysentery, typhoid and encephalitis B. Epidemic encephalitis was the highest in incidence in February to May of every year. The incidence accounted for 85% of that in the whole year. Encephalitis B was the highest in incidence in August to September and accounted for 85% of that in the whole year. Typhoid was the highest in incidence in August to October and accounted for 66% of that in the whole year. During the first winter and spring after the earthquake, stress was put on the prevention of influenza and epidemic encephalitis. In the whole prefecture the adults were generally inoculated against influenza (4 million person-portions). The children were generally inoculated against epidemic encephalitis (2 million person-portions). This reduced the incidence of these two epidemic diseases by 95% and 71% respectively; when summer came stress was put on dysentery, encephalitis B, and typhoid. Dysentery is an infectious disease which had the highest incidence, it is the easiest to spread and the most difficult to prevent. The prevention and treatment of dysentery was the main focus of the year. Comprehensive measures were put forward to mobilize the people and launch a mass movement to improve the hygiene in every household.

In the city stress was put on cleaning the ruins, excrement and urine, garbage, restoring the sanitary facilities and improving the appearance of the city. In the countryside stress was put on "two controls" (control of water, and control of excrement and urine) and "five improvements" (improvement of wells, toilets, livestock pens, kitchens and environment). A program of education on hygiene and eliminating diseases was carried out. Over one million man-days and 40,000 vehicles cleaned up 70,000 tons of garbage and sewer sludge in 3,700 places and repaired and built over 2,600 toilets and dug out 1,200 kg of maggot pupas thus, the sanitation was greatly improved. In the countryside of Tangshan Prefecture 3.4 million people cooperated in the movement to eliminate pests and diseases; they cleaned up over 4 million tons of garbage and dredged over 200,000 meters of sewers. The wells that provided water were restored to the level before the earthquake in Tangshan Prefecture. In 90% of the production teams the unified control of excrement and urine was implemented. Since this work was conducted early and well, the history of the spread of disease after an earthquake was changed. It was originally expected that 800,000 people might suffer from diseases in the following year. However, fewer than 83,000 people suffered from diseases in the month of August. During the entire year fewer than 100,000 people suffered from diseases. The children in the entire prefecture were generally inoculated against encephalitis B (1.5 million persons). The adults in Tangshan City and in the main disaster area were generally inoculated against typhoid III, IV, V and against cholera (2.2

million persons). In addition, inoculation against measles and infantile paralysis was conducted. All these measures played a very important role in controlling the spread of epidemic diseases.

3. The restoration of medical and health organizations and supplying medicines and appliances

After the occurrence of the earthquake the total damage to medical and health buildings in the prefecture amounted to an area of over 396,500 m^2, accounting for 87.6% of the original area. Of these damaged buildings those which completely collapsed covered an area of over 287,000 m^2. Over 11,000 hospital beds were smashed and over 1,450 sets of large medical equipment were damaged. The loss of fixed assets was estimated to be 28,325,000 yuan. The earthquake killed 1,901 people which accounted for 10% of the total health personnel. More than 1,200 medical workers were transferred to Tangshan from 25 provinces and cities including Liaoning, Jiangxi, Gansu, Heilongjiang, Shanghai, Guangdong, Ningxia, etc. One hundred thousand sets of medical appliances of 365 varieties, more than 50,000 varieties of medicines, and nearly 1,000 tons of epidemic prevention liquid medicine and vaccine for one million persons were transferred to the disaster area. This enabled the medical and health organizations to recover. In less than half a year simple hospitals, hospital beds and medical facilities reached 90% of those before the earthquake. The hospitals at the commune level all exceeded those before the earthquake.

The work of epidemic prevention the incidence of influenza, encephalitis, etc., which historically occurred in the winter and spring was greatly reduced during the first winter and spring after the earthquake. From January to August of 1977 there were 90,219 cases of various types of infectious diseases. The incidence was lower by 71.4% than the 312,687 cases during the same period of the previous year and lower by 32.9% than the average 134,447 cases of the same period from 1971 to 1975. Sixty-five people died so the death rate was 82.1% of the same period in an average year and lower by 52.2% than in 1975-1976.

IV. Strengthening Public Security and Rectifying the Social Order

After the earthquake a small number of people acted improperly. They seized the opportunity to start rumors and spread reactionary and superstitious remarks and created a mood of fear. They robbed private properties, raped women and disturbed the public order. In response the cadres, public security policemen and militias organized themselves quickly to guard banks, stores, storehouses, grain storehouses, etc., and to prevent sabotage. The Headquarters held a meeting of the cadres from the armed departments and public security departments of Tangshan Prefecture and Tangshan City. They studied and made arrangements for the restoration of public security organizations and public security work was conducted. After the meeting the departments of public security at various levels quickly strengthened the lead groups and restored the administrative offices.

Directed against the increase of the occurrence of political criminal cases the following measures were adopted by the public security departments. The first was to strengthen investigation procedures. The second was that the Public Security Bureau and the court organized special groups to handle cases in cooperation. On the 14th day after the earthquake a group of active counter-revolutionary criminals were sentenced for smashing, looting and raping.

Two more groups of criminals were sentenced in succession after this. Of these three groups 367 criminals were sentenced. Of these criminals 26 were guilty of the most heinous crimes and were sentenced to death and immediately executed by shooting. At the same time the criminal organizations were publicly sentenced. These actions frightened the enemy and encouraged the people. The third was to mobilize the people to expose criminal activities. According to incomplete statistics 9,985 cases were exposed and accused and 129 criminals surrendered themselves to the police, 9,100 cases of various problems were confessed, and large quantities of smashed and looted properties were seized. The fourth was to strengthen the guarding of key targets. The fifth was to mobilize public security organizations at basic levels and make clear the behavior of the bad elements and persons suspected of criminal activities, and to strengthen supervision and control. At the same time, the checking of households in the city and countryside was conducted to verify the number of people killed by the earthquake and verify the number of the present occupants. Social public security education to the public was conducted and people organized to protect the autumn crops, highways and railways. In Tangshan City a program for returning items was launched and many lost and scattered materials were collected.

While maintaining public safety the work of fire protection was taken note of. After the earthquake the people's self-constructed simple houses were made from reed mats, asphalt felt and wood boards all of which were flammable. Furthermore, the tent houses were very close to each other and had many potential fire sources. Once a conflagration started there was the danger of burning all the connected camps. Therefore, education on fire protection safety was widely conducted and fire protection rules were made and examinations of fire protection safety were done from time to time. Simultaneously the construction of specialized fire protection brigades was strengthened thus, large conflagrations were avoided.

The Party Committees of Tangshan Prefecture and Tangshan City along with troops from various units organized propaganda cars to go through the streets one after another and propagate the profound concern and sympathy of Chairman Mao and the Party Central Committees. More than 100,000 officers and men, medical team members, and supporters went from household to household and to tents expressing the sympathy of the Party Central Committee. They also made use of various propaganda forms to explain the incomparable superiority of the socialist system, to explain the great truth that "man can conquer nature", and explain scientific knowledge about earthquakes. The news and publishing units etc., also gave prominence to earthquake relief. Up to September 9 the Hebei Daily published 85 pages of reports and comments about earthquake relief, 2 pages each day in average. The Hebei Broadcasting Station broadcasted 162 items about earthquake relief. The Hebei TV Station shot 3,500 m of film about earthquake relief and showed 69 pieces of TV newsreels. The Hebei Peoples' Publishing House published 13 types of books and pictures, more than 1,500 volumes (pieces). On August 2 broadcasting was restored in Tangshan City and in surrounding areas. On August 4 the "Tangshan Labor's Daily" was restored. On September 12 the people in the disaster area could watch TV.

V. Restoration of Production

As for the restoration of industrial production, the emphasis was put on the large enterprises which had great influence on the national economy. Industries supporting agriculture and light industries which had a direct relation with earthquake relief and peoples lives were also given importance. The central government attached great importance to the restoration of production at the Kailuan Coal Mine and repeatedly stressed the importance of again producing coal and increasing production. Efforts were first focused on draining water that had accumulated because the electric power failure had stopped the pumps. The Ministry of Metallurgical Industry set up a lead group to restore Kailuan. Many iron and steel factories indicated that they would produce any type and any quantity of steel needed for the restoration of Kailuan. The lead members of 38 factories under the Ministry of Machine Industry came to Kailuan to do an investigation and to arrange for supporting items. The workers and staff members of the railway said they would transport materials needed by Kailuan as top priority. The construction supporting contingents came from Liaoning, Jilin, Heilongjiang, Shanxi and Shanghai and engineering troops and design personnel from 10 design departments from all over China worked day and night at the Kailuan Coal Mine from shortly after the earthquake until the restoration. A total of 84 million tons of water was drained from the mine pits and 1.25 million m^2 of ground buildings were rebuilt in only half a year. In a short period of time 7 of the 8 individual coal mines were restored and back in operation. The Ministry of Metallurgical Industry and the Ministry of Power and Water Conservancy undertook the restoration of the Tangshan Iron and Steel Corporation the Tangshan Power Plant, and the Douhe Power Plant. The workers and staff members of the Tangshan Iron and Steel Corporation cooperated with workers, engineers and technicians from the Anshan Iron and Steel Corporation the Baotou, Wuhan, Taiyuan Iron and Steel Corporations and a large number of officers and men from an army engineer company. First priority was given to repairing the No. 1 Steel Making Works. Less than one month after the earthquake the first steel was made. It was followed by the restoration of production at the Medium-sized Steel Rolling Factory, the No. 3 Steel Rolling Factory, and the Small-sized Steel Rolling Factory on September 30, October 1, and November 1, 1977, one after another.

Restoration of the light industries was also conducted very quickly. The Party Committee of the No. 1 Porcelain Factory of the Tangshan Porcelain Corporation with the help of the PLA went all out to mobilize the workers. They removed collapsed buildings to look for wood materials and shattered the broken concrete beams to get reinforcing bars. They rebuilt the bone china workshop, which covered an area of 3,600 m^2 in only 20 days. Up to the end of 1976 the workshop completed the task of successfully producing 6,800 pieces of export bone china.

As for the restoration of agricultural production, the State Council demanded that a bumper harvest be achieved in the same year and an increase of yield be achieved in the next year. The Party organizations in the countryside fully mobilized the workers to utilize the middle and later periods for the autumn crops. Each production brigade was usually divided into two units, one to take care of the injured people and organize people's lives, and the other was to drain accumulated water from the fields and to fully utilize available farmland. In the whole prefecture nearly 2 million workers were engaged in the relief and reconstruction. On the 3rd day after the earthquake 60,000 militias turned out to dig ditches and drain water in Luannan County to relieve over 0.3 million mu of land from the danger of accumulated water and to remove pests from 3 million mu of land. Thus, the normal growth of crops was guaranteed.

Before planting wheat in Tangshan Prefecture 3,300 large, medium and small tractors and 1,600 sets of matching implements were allocated in order to support the restoration of agricultural production in the disaster area. The Luoyang Tractor Factory sent a team to transfer 100 tractors from the factory to the disaster area and it also organized 30 technicians to go into the communes and brigades to teach the necessary technology. More laborers were injured and killed in Fengnan County by the earthquake and the loss of livestock was more serious. In addition, the autumn crops in 1976 matured late and the wheat planting time was shorter than in previous years. Thus, a lot of difficulties occurred in planting the wheat. They used manpower, livestock, and machines to speed up the rate of planting the wheat and they fulfilled the task of planting ahead of schedule. In the entire prefecture 4.1 million mu of wheat was planted which exceeded the original plan.

Quickly repairing the water conservancy engineering of the farmland was the key to restoring agricultural production. After the earthquake people organized to temporarily repair the damaged dams and reservoirs to guarantee safety during the flood season. Then, Hebei Province concentrated on having 200,000 civilian workers transferred. During the last 10 days of September 1976 river harnessing contingents from 8 prefectures left for the work sites. The river harnessing contingents from the prefectures of Handan, Xingtai, Hengshui and Shijiazhuang were neither stopped by wind nor by rain and traveled a great distance to the work sites. Twenty thousand civilian workers from Longfang Prefecture went to the disaster area by foot. Up to March 1977 the main items, which were repaired and restored to operation, included three reservoirs on the Douhe River, Yanghe River and Qiuzhuang River, three embankments and facilities in Luanxian County and Leting County for the Baigezhuang water conveying main channel, and water draining east of Luanxian along the Luanhe River, Huanxianghe River, Douhe River and Shahe River. In total 37.6 million m^3 of earth was handled.

While repairing large water conservation projects 30,000 well-drilling team members from 8 prefectures of the province were transferred to the disaster area with 1,300 sets of drilling machines, over 200 sets of air compressors, electrical testing meters, and 8,000 sets of dies to thread the well pipes. Closely working with the cadres and people they started a people's war to repair the old wells and drill new ones. Up to the end of March 1977, 37,220 new wells had been drilled and 26,410 damaged wells had been repaired and the water conservancy projects in the small farmland were restored to the level before the earthquake through the joint efforts of the supporting contingents and local people.

VI. Rebuilding of Tangshan

The remains of the old buildings were removed and a new city plan was prepared. The city was then completely rebuilt to form a new Tangshan. At the 20th anniversary of the earthquake the city appeared to be a model for other cities in China; clean and prosperous. The industries in the city and the port serving the city had been rebuilt; and the population of the city exceeded the pre-earthquake population.

Photo 1. Removing victims from underneath the rubble of buildings.

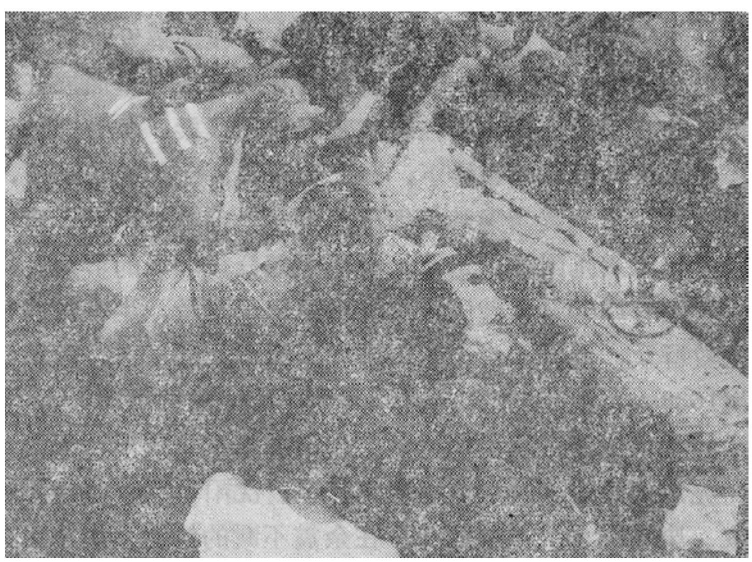

Photo 2. Saving survivors excavated from the rubble.

THE REPAIR AND RESTORATION OF THE KAILUAN COAL MINE

Mi Enli*

I. General Description

The Kailuan Coal Mine had a history of over 100 years since it was set up in 1879. Before the earthquake there were 8 production pits with an annual raw coal output of over 20 million tons. Because of the coal, Tangshan was a center of heavy industry and the availability of coal was very important to the economy of China.

Earthquake forces were not taken into consideration for the buildings and structures at the Kailuan Coal Mine. The subordinate pits and factories were all located in areas of intensity IX to XI. All types of buildings and structures were seriously damaged. The buildings on the ground surface mostly collapsed completely and most of the substation transformers were smashed so all the electric power went off. This paralyzed the ventilation and drainage systems of the pits in the entire mine area. In the entire mine area 70% of the mining levels and 60% of the coal faces were inundated. Some of the pit shafts had displacements and cracks and some tunnels collapsed. More than 30,000 sets of machinery and electrical equipment on the ground surface and in the pits were smashed and inundated. The surface railways, communication circuits, water supply network, and communication and transportation installations were damaged to various degrees. All the production in the pits stopped. Both the direct and secondary disasters of the earthquake were very serious.

The electrical power supply was restored in the mine area three days after the earthquake. The first lot of coal was produced at Majiagou Mine ten days after the earthquake and production was completely restored at Lujiatuo Mine four months after the earthquake. In one and a half years over 160 million tons of accumulated water was drained from the pits in the entire mine area. Over 370 km of tunnel and more than 100 coal faces were repaired; over 33,000 sets of machinery and electrical equipment were overhauled and more than 1 million m^2 buildings were restored. By December 1977 the daily output of raw coal reached the level before the earthquake.

When the magnitude 7.8 earthquake occurred in Tangshan all the power went out in the pits in all the mines. The water level in the pits increased and the safety of over 10,000 miners and staff members was seriously threatened. Fortunately, the emergency exits in the pits and the ventilation installations in the tunnels were not seriously damaged. After the earthquake all the workers and staff members working in the pits returned to the ground surface through emergency exits (the personnel in Lujiatuo pit returned to the ground surface through the ladder rooms in the shaft wells).

* Kailuan Coal Mine

II. Draining Water from the Mines

1. Principles and measures for draining water

Since the power supply was suspended the original water drainage equipment in the pits was all in a state of paralysis. The pits which drained water to the ground surface in one stage (e.g. Jinggezhuang Mine) completely lost the capacity to drain water because the pump rooms at the bottom of the pits were all inundated. In the pits of the multi-stage relay ground water drainage (e.g. Linxi Mine, Zhaogezhuang Mine, etc.) the equipment in the upper tunnels could not be brought into service because the pump rooms in the lower tunnels were inundated. Furthermore, the volume of water pouring into the mines after the earthquake increased in time and the pits were inundated. By the middle of August in the entire mine area 70% of the production levels, 58% of the slopes, 56% of the main water drainage pump rooms in the pits and 53% of the high head water drainage pumps were inundated. If the water levels continued to rise all the pits would have been in danger of being inundated. The steps used for restoration were as follows. The first step was to ascertain the water situation and to quickly repair and restore water drainage in the pump rooms which were not inundated. The second step was to build equipment to increase the capacity for water transfer and drainage. The third step was to increase the comprehensive capability of water drainage and to focus on removing the accumulated water from the pits and to restore the normal water drainage system. The specific methods were as follows:

1) Correctly calculate the volume of accumulated water and rate of water inflow.

2) To seal and block the water inflow locations which could be sealed in the tunnels that were not inundated. For example, to shut off the drilled holes which carried inflow of water.

3) To eliminate back flow to avoid draining water from the lower tunnels to the upper tunnels or to avoid the above ground water from flowing back into the pits or the lower tunnels.

4) To set up water gates in line with the specific conditions to draw water to the temporary water drainage systems which were set up or to the secondary tunnels to protect the important places such as the pump rooms.

5) To try to restore the pump rooms which were not inundated first. As for the motors whose insulation performance was reduced and did not conform to the specifications, idle running was conducted to gradually improve their insulation. For other electrical equipment replacement was done.

6) To set up a new water pursuing system. The so-called water pursuing was to make use of various movable pumps (pump groups) to pursue and pump water to the fixed pump rooms for transfer to the ground surface. The capacity of the water pursuing pumps was 2 to 2.5 times that of the water to be drained.

7) To set up and transform the fixed pump rooms to increase the water drainage capacity.

a. To enlarge the original water drainage capacity of the pump rooms. The first measure was to install the new pumps, the second was to change the small pumps into big ones.

b. To set up a new water transferring drainage station to transfer drainage water section by section and to use existing tunnels as part of the water transferring drainage system.

2. Several better ways for water pursuing and drainage

(1) Water pursuing and drainage with horizontal pumps in the shafts

This method of water drainage was used more often. With this method the pumps and motors were mounted to drain water from the shafts. The pumps and motor were gradually lowered as the water drained. The mounting included two methods, i.e. mounting with hangers and mounting with cages. Mounting the pumps with cages for water drainage was used in the auxiliary shafts of Fangezhuang Mine. The pumps were operated for 142 days and the total water drainage was 1.3596 million m^3. The superiority of the shaft water drainage with horizontal pumps over inclined shafts was that the pumps had fewer mechanical troubles and there was less workload in the installation of pipes. The shortcomings were that more mounting equipment was used and the installation and mounting technology was more complicated.

(2) Lifting water with skips in the shafts

The skips were refitted into the water lifting equipment, i.e. two small gates were made in the bevel faces of the bottom side in each skip. When the skips contacted the water surface the small gates were opened automatically and the water entered into it. When it was lifted upward the gates were closed by the water pressure and the dead weight. The skips were lifted to the unloading locations at the openings of the shafts where the water flowed away through a water "receiving trough" and water pipes. The water lifting capacity of the skips at Fangezhuang Mine was 400 m^3/hr. In 4 months 0.567 million m^3 of water was lifted. The advantages of this method of water lifting was that it could make full use of the original equipment in the pits, it had less workload in refitting, it was simple in operation and there were fewer accidents with machinery and electrical equipment.

(3) Pressing air to drain the water in the shafts

This method of water lifting was to feed compressed air into the mixing rooms to mix with the water forming a milky liquid which was then drained to a predetermined height. As the lower density mixed liquid rose the new water came in at the bottom and the water in the pit shafts was continuously being drained to the ground surface. The advantages of this method of water drainage was that less space in the pit shaft was occupied, it was simple in installation, the equipment was reliable in operation, and had a large capacity. The disadvantages of this was low efficiency, large power consumption and that it was unable to completely evacuate the accumulated water at the bottom of the pits. Therefore, it was only used as an auxiliary measure.

(4) Pursuing drainage of water through submersible pump groups in the shafts

The pump groups were divided into two categories: single-pumps and series-pumps. This method of drainage had the following advantages. One was large in drainage capacity. In the pit shaft, with a diameter of 5-6 m, the drainage could be up to 4,000-6,000 m^3/hr with the head up to 300 m in height. Another advantage was that it was better in adaptability. The operation was not affected by the water in the pit shaft, by gas or the change in the water level, and the water

drainage volume could be adjusted by changing the number of pumps being operated. The third advantage was easy installation. The submersible pumps could be inserted at a predetermined depth and operated continuously until the water was drained to that depth. The disadvantages were that the life of the submersible pumps was relatively short, stable voltage was required and the technologies of maintenance, handling, installation and operation.

(5) Pursuing drainage of water with horizontal pumps in inclined shafts

The pumps were installed on pump carts or sliding sledges. The pump carts were used in larger section inclined tunnels with rails. If the tunnel sections were not large and the tunnels and rails were seriously damaged then sliding sledges were used. The anti-inclined pump carts could be used for the sliding bearing pumps or when the dip angle was larger than 20º. This method of water drainage had the advantages of being quick and simple in installation, it was possible to use on big and small pumps, and was quick in effect. The disadvantages were that as the water level lowered it was difficult to move the pumps and connect the pipes, and the operating conditions were poor and it was a less efficient method of water drainage.

(6) Pursuing drainage of water with deep-well pumps in the inclined shafts

This was a special method of pursuing drainage of water. It was used in cases where the dip angles of the tunnels were large and the sections were small or irregular. It had the advantages that it was not necessary to move the pumps from time to time when the water level varied over a large range, it was high in utilization ratio and simple and flexible in management. For example, by making use of the limited space near the belt-driven machines many sets of deep-well pumps were connected in a series and installed at Linxi Mine. A good water drainage effect was achieved.

(7) Pursuing water with submersible pumps in the inclined shafts

This method was used when the dip angle was larger than 30° and it was difficult to use horizontal pumps. For example, in one section of a tunnel of the No. 11 level inclined shaft at the Tangshan Mine (35° in dip angle and 280 m in inclined length and a section of 3.6 m x 2.8 m with no rails), eight submersible pumps were used to drain the water.

(8) Pursuing drainage of water with the combination of inclined shafts and drill holes

This method of water drainage was used in difficult conditions. For example, at Fangezhuang Mine four holes (367-267 mm in diameter) were drilled downward from the ground. Of the four holes two were used for ventilation and two were used for water drainage. The inner casing pipes had check valves at the lower end and they were connected to pipes from the pumps down the shafts and the water was drained directly to the ground surface. From November 25, 1976, 0.493 million m^3 of water was drained in 86 days. The results were very good.

3. Suggestions for improving future designs

1) There were two types of water drainage systems at the Kailuan Coal Mine: a) the water was drained to the ground surface in one section; and b) the water was drained to the ground after transferring drainage from many sections. As for the former, once the pump rooms at the

bottom of the pits were inundated the pits were subsequently inundated, but the pits where the multi-section transferring drainage of water was used the intermediate pump rooms could be kept in operation. Therefore, for future new pit designs the following preventative measures should be considered.

a. A proper size pump station should be set up above the water surface level in combination with the pump type to be used to drain the shaft tunnel pursuing water below the water surface level.

b. A water gate should be set up near the cart lot at the bottom of the pit. If necessary, the main water resources area sub-stations and the pump rooms can be separated. This can ensure the safety of the pump rooms and is favorable for water drainage and the restoration of mine operation.

c. It is proper to merge the multi-stage water drainage system and to make the multi-stage water transferring drainage a two-stage system.

2) In multi-level pits when the power is off the lower level shaft tunnel in fact becomes a big water storehouse. In order to avoid the water level from rising to the level of the pump rooms the standard height of the pump rooms should be higher than the level of the opening of the shaft.

3) In order to prevent water accumulation after an earthquake it is proper to increase the installed capacity of the main pump room. At the same time the water gate at the opening of the shaft is set up and the lower tunnel is used as a regulating water storehouse.

4) High head should be considered when building a new pit. Large flow submersible pumps can be used as substitutes for the present horizontal pumps.

III. Repairing and Strengthening Well Tunnels Including Pit Shafts, Cave Rooms and Tunnel Passages

Various cave rooms located on different levels suffered light damage. Most of the cave rooms basically remained undamaged. Only a few suffered damage but it was not serious.

In the mining district various tunnels which needed repair after the earthquake made up 16% of the total in length. The tunnels which suffered the most serious damage were at the Tangshan Mine and 32% needed repair for falling rock. The toppled down places were handled with arch supports and driving wedges and filling in with waste rocks.

There were 62 pit shafts in total at the Kailuan Mine among which 26, or 42%, suffered damage of different. The major damage included falling plates of rock from the well wall, cave-ins, oozing-in of mud and sand, ring cracking on well walls and vertical cracks (most taking place in brick or stone lined pit shafts) or X-shaped cracks where the pit shaft passed through alluvium of the Quaternary period where broken sections of the wall gushed water and oozed sand. There were 2 shafts that could not be repaired due to serious peeling off of the wall and being blocked up.

For repairing pit shafts concrete rings with anchored metal-net or steel channel reinforcement were adopted. To illustrate, a number of examples follow.

1) The pit shaft of the No. 3 well at the Tangshan Mine was built with brick or laid stone. After the earthquake the well wall was broken over a length of 220 m from the lower part to the upper part; a vertical crack had a length of 10-20 m, a width of 10-20 mm and faulted inward 200-300 mm at the No. 7 level dock gate. The anchor-net reinforcement method was adopted to repair this pit shaft. First, they removed the bricks and stones which faulted inward or were loosened from the upper to lower sections, then anchor rods with a diameter of 16 mm were driven in 1.5 m with spacing of 600 mm. The wire network was tied to the rods then they washed the pit shaft by using pressure-water and finally, cement concrete was sprayed for coating.

2) The pit shaft of the new well of Xujialou in Tangjiazhuang was built with reinforced concrete. It passed through the alluvium of the Quaternary period with a thickness of 92 m. Because of liquefied sand the well tower sank, slanting as a whole. At the construction joint near the mouth of the well and the joining of the single layer well wall with the double-layer well wall, 13.23 m under the well mouth, a ring-shaped crack was found; the dislocation of the crack was 110 mm. When repaired, within the range of 0.5 m above the crack to 3 m below the original crack, the concrete was chiseled 50 mm in depth then 15 well rings made of No. 20 channel steel were mounted with a spacing of 200 mm. The steel rings were connected to the original well wall and anchored as a whole by reinforced bar-resin-anchors. Meanwhile, vertical bars with a diameter of 25 mm and a spacing of 150 mm, were tied in place and ring-shaped bars 22 mm in diameter with a spacing of 200 mm were also tied in place. Finally, No. 200 concrete with a thickness of 150 mm was grouted over the steel.

3) The auxiliary well of Fangezhuang Mine went through a thickness of 78.62 m of alluvium of the Quaternary period. When the well was built the freezing method was adopted but its quality of construction was poor. After thawing, several building joints leaked water so grouting to block the leaks was conducted a number of times. After the earthquake, the whole well wall had fallen down at the connection of the well neck and the well wall. Along the well height several water leakage points were found. The water gushed in the pit shaft increasing sharply, reaching 41.8 times the amount before the earthquake. Besides, some fine sand also oozed out. During repairs they chiseled the crevices and mended them first then 9 of channel steel well rings were mounted to support the well wall temporarily. On May 12, 1977 after the Ninghe aftershock the sand oozing took place again so the double-liquid-in-wall-grouting method was used to stop the leakage. Finally, driven-in rotary spray stakes were used from the ground face to reinforce the pit well.

4) For the auxiliary well at Lujiatuo Mine, the pit shaft went through 59.69 m thickness of alluvium of the Quaternary period. During construction the shaft was too big due to the slanting of the frozen hole, after tunneling in, the well's wall was not laying up properly. Soon, water permeability took place at a depth of 62 m in the pit shaft and sand, gravel and pebble also oozed into the well. At the upper portion of the pit shaft a big cave-in was formed. After the second time it became frozen the well-digging began again and a vertical crack in the well wall 8-10 m in depth underground was found. Going down to a depth of 34 m the crack was even more serious, 12 mm in width by 26 m in length. Therefore, an additional well wall with a thickness

of 250 mm was built from the well neck to 131 m below ground. After the earthquake the cracked pit shaft rifted and displaced (the biggest displacement was 30 mm) in a slanting direction; at the rifted places sand oozed and water sprayed. Because the smallest clearance between the well wall and lift cage was only 190 mm a compacting method was adopted to stop the water leakage. For the original hot air opening, which had been discarded and blocked up, the well rings made of No. 20 channel steel were used with a space of 300 mm between them for temporary support. Afterwards, concrete was sprayed 200 mm thick then a tied steel bar net was put on and more concrete was sprayed on with a thickness of 100 mm. For the rifted and displaced areas of the pit shaft, 3 well rings made of No. 20 channel steel were used to enforce them and water-glass cement pulp was pressed in. Finally, a thickness of 50 mm of concrete was sprayed on. At the places where there were many more concentrated cracks the pulp injection pipe remained temporarily in case one more spraying was needed.

5) The pit shaft of the air well at Lujiatuo Mine went through 48.68 m in thickness of alluvium of the Quaternary period. The well depth was 102.55 m with a diameter of 4.5 m. After the earthquake, near the two air cave openings, the well wall split open and showed faulting and displacement of 130 mm. When repaired, within the range of 2.4 m from the bottom plate of the east air duct to 9.5 m below the well mouth, 4 well rings made of No. 20 channel steel were set up; a steel bar net was laid on them to be welded together. Finally, 200 mm thick concrete coating was sprayed on. Over the reinforced section of the well ring, near the two openings of the air duct within a height of 4 m, one layer of the well wall was chiseled then 200 mm thickness of concrete was sprayed on and finally, a single layer of rotary spray stakes were driven in around the pit shaft to enforce it. The crossing point of the air duct was reinforced from outside of the pit shaft with reinforced concrete then filled with lime concrete and rammed solid.

IV. The Recovery of Ground Construction at Kailuan Mine

1. The recovery principles of on-ground construction

The repair of ground construction was divided into 4 categories i.e., production system, necessary production engineering, residential buildings, and other buildings. In the light of their urgent and important requirements all the projects were rebuilt on their original sites according to their original scales and areas. For some of the unsuitable parts a number of adjustments were made on the basis of production needs. During reconstruction earthquake intensity VIII fortifying was done.

2. Positive measures were taken to save buildings which rifted but had not toppled down

For the buildings which rifted but had not yet toppled down the principles were: damaged buildings that did not need to be torn down would remain in place; for those that could do their duties only after being strengthened such work was conducted. Compared to reconstruction strengthening could save building materials. Take steel for example, it would require less than 10-15 kg per m^2 building area which is for a new building so the cost would be reduced by 60-70% and the progress of ruin cleaning could be shortened by 1/3 or so.

3. Recovery of the production system and the necessary projects

(1) Pit shaft

The pit shaft was the throat of the mine well. The recovery of derricks and well towers were the key projects for fast repair of mine wells.

1) There were 15 steel derricks and all had some slanting, staff bending, shearing off of connection joints, and so on, to different extents though not serious. The repair methods included: pulling by winch, straightening and making them upright by jack hoisting, then enforcement was made or some staff rods were replaced.

2) There were 12 steel derricks with brick supporting structures. The lower portions of the brick structure were seriously damaged in general. Except for the air well derricks of Tangjiazhuang, which were renovated as steel ones, the rest of the brick post derricks, which did not topple down, were all made with high-grade mortar joints.

3) One reinforced concrete derrick was poured-in-place. After the earthquake its lower standing frame made of reinforced concrete and the brick abutment of the well opening room were all damaged. The strengthening was to wrap reinforced concrete around the lower standing frame and to make a reinforced concrete abutment to replace the brick one.

4) There was one brick derrick which suffered slight damage after the earthquake. When repairing it they removed the rifted part of its slanting leg and mended it, and reinforced concrete 120 mm thick was wrapped around it.

5) There were 2 well towers built with poured-in-place reinforced concrete. The round tower of Xinfeng well at the Tangshan Mine, which was 12 m in diameter, was located on the earthquake fault. During the earthquake approximately 6 m of its lower portion cracked and fell and leaned against the inside wall of the tower. After it was removed a steel structure well tower was rebuilt. The square well tower of Xujialou, Tangjiazhuang Mine had a ring-shaped crack and its whole body inclined 270 mm in a southwest direction and when repaired only part of its body was enforced.

(2) Repairing winch rooms

There were 32 various winch rooms in the mining district, most of them were brick/concrete structures combined with a basement. During the earthquake the basements suffered slight damage while the buildings above ground suffered serious damage. Among the 32 winch rooms 8 of them were strenghtened and 24 were rebuilt. When the key well winch room at Fangezhuang Mine was rebuilt its basement walls were covered with reinforced concrete.

(3) Coal bins and waste rock bins

37 various bins including one of the round tube-shaped brick bins at Fangezhuang Mine, toppled down, even some built with reinforced concrete. Except for these 37 bins, all the others were reinforced concrete structures and no serious damage was found. Still, repair and reinforcement work was conducted on them.

(4) Conveyer belt passages

There were 78 conveyer belt passages in the mining district. Most of their bottom portions were frame structures and their upper portions were brick-concrete structures. After the earthquake most of their upper portions toppled down. When repaired, all of them were rebuilt with a light frame structure. As for the lower frame structure part, most of them were reinforced as well. Using the Xujialou conveyer belt passage as an example, during repairs the concrete at the bottom of the frame column was chiseled and the steel bars were put in place; then the frame was set upright by a winch and finally, concrete was poured at the bottom of the frame columns.

(5) Key factory buildings of the coal washers

There were 6 coal washers including 14 key factory buildings, which were all multi-story buildings. Their structure pattern could be divided into 3 categories: 1) reinforced concrete structures; 2) inner frame structures of reinforced concrete; and 3) two bottom stories having a reinforced concrete frame and the other stories above having a steel frame or inner steel frame. After the earthquake all these coal washers suffered damage to different extents. The Tangshan mines suffered the most serious damage. Their frames, column ends, and beam ends were all cracked, the concrete was crushed, and the steel bars were bent in the form of a lantern. During repairs most were strengthened by being wrapped with reinforced concrete. Some were repaired when the bottom of the frames were lifted with jacks and the columns were repaired.

V. Repair of Mechanical and Electrical Equipment

The Kailuan Coal Mine was one of the enterprises with high-level mechanization. There had been 84,131 sets of mechanical and electrical equipment registered at the Bureau. When the earthquake took place 55,100 sets of equipment were operating.

The mining power system was mainly composed of lifting, draining, ventilating and power supplying systems.

1. Equipment maintenance

On October 14, 1976 an equipment damage investigation group was set up. The group conducted check-ups on nearly 100 sets of equipment i.e., 7 transformer substation caves in the 8 tunnels of Majiagou, 2 digging-in coal faces, one stope, one central pump room, and one air compressor room. The results showed that among these the mechanical equipment suffered less damage; the mechanical structure basically had no damage, and the decelerator became rusty after being submerged but if there was medium damage small repairs were conducted so they could operate normally. The electrical equipment was badly damaged. Their insulating was completely damaged and only an overhaul could make them work again.

In early December a large investigation group was set up again. An overall investigation and study was conducted on mines and the results showed that only a small portion of the submerged and buried equipment was seriously damaged and not worth being repaired. They needed to be replaced by new ones. 70% or so of the electrical equipment, which was submerged and buried, needed an overhaul.

The specific measures of fast repair on equipment were:

1) A general survey was conducted on the submerged and buried equipment in order to work out a repair plan.

2) To organize a repair contingent on the basis of the repair plan and assign tasks to each group.

3) To prepare parts, fittings, and materials and to sort out the spare parts and fittings in storehouses as well as in workshops; a replenishment plan should be worked out.

4) The equipment stored in surface buildings or in upper tunnels must be repaired first.

5) The site, equipment, tools and materials for washing, rust removing, drying, laying and repairing of parts and fittings must be ready in advance. Besides, the work of washing, rust-removing, grease-smearing and antifreeze must be done.

2. Power supply systems

1) Recovery of 35 kV systems

After the earthquake, though the electrical equipment suffered damage, the 35 kV wire was slightly damaged. Three days later a repair contingent organized by the Ministry of Water Conservancy and Electrical Power was sent to Tangshan to repair on the electrical network. According to the circumstances at that time the substation of the Tangshan Mine could not transfer 35 kV electrical power so its capacity fell from 35 kV to 6 kV. All the others still transferred 35 kV. The maintenance work on the power supply line was the responsibility of the electricity department, and all the units of Kailuan Mine were responsible for their own substations. They created conditions to meet their own requirements for power and by doing this, each mine began to have electricity on July 31, one after another. In the 2nd step, some temporary substations were set up to handle drainage for the recovery of production. Having electricity, every unit organized manpower at once to clear the ruins and to prepare for the set up of temporary substations at the original site or at other places. If DC electricity was used storage batteries should be adopted. The 3rd step was to set up permanent substations, which were designed by the department concerned at original scale or for a long range plan. After approval from the Mining Bureau the project was built.

2) Recovery of 6 kV power lines

The recovery of 6 kV power lines started somewhat later. The first thing was to give power to such units as water supplies, drainage items, lifting, ventilation and hospitals. When the situation was good daily-lighting could be provided. The main measures taken were to make the fallen and slanting poles upright again and to repair and connect broken power lines. Then, after being checked, if all was well the power was turned on.

3. Recovery of electrical equipment in the pit

Being submerged by water was the main problem of electrical equipment in the pits. By being submerged the high or low-pressure switches, transformers, rectifiers and other equipment

had their anti-explosion surfaces become rusty, meters failed to work and their insulating property was lost. Some needed to be replaced with new ones and some needed to be heated to remove moisture.

When submerged the oil-soaked low-insulating cable in the pit, should have the water-soaked part cut off so the remaining part could be used? About 30% of the cable in the pit needed to be replaced.

EARTHQUAKE RELIEF WORK IN THE TIANJIN URBAN DISTRICT

Tong Enchong*

When the earthquake occurred in Tangshan City the earthquake intensity in the Tianjin municipality, about 100 km away, was VI-IX with VIII in the urban area and the damage was great. After the main earthquake aftershocks took place continuously. The residents in the urban district went out onto the streets so the main traffic streets were blocked. As a result industrial production and peoples lives were greatly disrupted. When the magnitude 7.8 earthquake ended the Tainjin Municipality Committee of CPC convened an emergency meeting attended by the standing committee members and other related members. At the meeting an Earthquake Relief Headquarters was established and earthquake relief emergency measures were taken at once including dispersing the inhabitants especially the old, the sick, the weak and the disabled people to safe places. They organized medical forces in the city to give first aid to the injured. They mobilized the employees of commercial departments to handle material supplies and called upon the inhabitants of the city to take precautions against fire and theft and to cooperate with public security officers in maintaining public order so as to prevent criminal activities. Meanwhile, all the factories and enterprises which could carry out normal operations were directed to go on with production.

I. Repairing the Water Supply System in the City

1) Urban district

1) Through an effort of 4 days and nights, 3 main pipelines and 2 lines crossing the river were repaired and the water supply to the main trunk line in the urban district was restored.

2) Emergency repairs on 142 deep wells was done one after another to recover the water supply to the central city.

3) Leaks in the main pipelines were inspected and repaired.

4) Repairing and reinforcing eliminated dangerous situations at more than 20 locations.

5) There was an increase of 113 temporary vertical water valves at 58 locations.

After one month's repair the water supply reached 0.4 million tons per day. The problems of the water supply needed for daily use by inhabitants and industrial production had been solved.

2) Hangu District

Pressure-replenishing wells and water-source wells were the main projects of the repairs. Next was to repair cast-iron trunk piping bigger than ϕ75 mm in diameter. By October 1976 one-third of the trunk piping was repaired. By the end of 1976 all the trunk piping and parts of

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the branch pipes were repaired and water could be supplied to the section. In the first half of 1977 the water supply was recovered to the level before the earthquake.

3) Tanggu District

After the earthquake the repairs were organized immediately. On the afternoon of July 28 the water supply began to gradually be recovered. Up until the middle of September the water supply had recovered to 50% or so of its capacity, i.e. 10,000 tons daily, and by the end of 1976 it had recovered to the normal amount.

II. Repair of Coal Gas Equipment

1) Natural gas

Emergency measures were taken after the earthquake to prevent explosions or fires from natural gas.

1) The electricity to the pumping station was cut off immediately. The main valves of the intake and outlet at the pumping station and at Liulin Station were shut off. Gas supply to the urban district was temporarily stopped.

2) All the pipe networks and gas facilities were inspected with 1 kg/cm^2 of pressure. On the third day after the earthquake the high-pressure bypass pipe at the pumping station was turned on temporarily to provide gas to hospitals and other medical units located in the urban district. After August 9, the gas supply volume increased gradually and at the end of August the gas supply reached two-thirds the level before the earthquake. Entering October it basically reached the pre-earthquake level.

2) Liquefied petroleum gas

If there was any damage to gas-filling stations temporary measures were taken to support or strengthen it, then production went on.

III. Emergencies of the Electrical System

1) Junliangcheng Power Plant

When the earthquake took place there were more than 70 workers on duty. They carefully examined the equipment using flashlights and tested more than 250 operating items to make sure that the electrical power network was connected properly and did emergency repairs on equipment. Two sets of generator units were restored to operation within 2 hours. The other 2 sets were put into operation on the 4th day after the earthquake.

2) Tianjin No. 1 Power Plant

There were 6 sets of generating units whose switches cut off automatically during the earthquake. By quickly negating the cut-off device 3 of them kept running normally. The

personnel on duty conducted more than 30 tests and showed that the safety of the power supply was guaranteed.

3) Yangliuqing Power Plant

The workshop buildings suffered slight damage during the earthquake and their operation was normal.

IV. Removing a Dangerous Situation at the Yuqiao Reservoir

A measure of press-pouring slurry to plug a crack was immediately taken after the earthquake with good effect.

V. Removing the Dangers of Explosives and Acute Poison of Chemical Products

1) Tianjin Chemical Plant

Before the earthquake measures were taken to improve the stability of the 3 liquefied chloride tanks so that no disaster would occur during an earthquake. After the earthquake the control gate was shut off immediately. The original cast-iron throttle was changed to an automatic throttle.

2) Tianjin No. 2 Organic Chemical Plant and Synthetic Fiber Mill

There were tons of stored intermediate intense poisonous gas (cysteine gas) when the earthquake took place. The personnel on duty handled the control gates one by one according to the technical procedures and as a result avoided a dreadful secondary disaster.

VI. Repair of Telecommunication Equipment

1) City telephone office

When the earthquake took place telephone calls could not go through due to damage to the building. After the earthquake the unbroken equipment, underground rooms and temporary telephone lines were utilized to guarantee that key lines would go through first. Meanwhile, the danger to both buildings and equipment was removed and repair work was actively carried out.

2) Telegram building, wave-carrying building and long-distance station building of the long distance exchange

The quake brought light damage or no damage and communication could be operated normally.

3) Post Office building

During the earthquake the Post Office building collapsed. The number of letters and telegrams sharply increased and it was too difficult to deliver them so there was a large buildup of undeliverable items. Under these emergency circumstances a special measure was taken to

mobilize some agencies that had special telegram units of their own to help receive and send important telegrams for railway, aviation and electrical power departments. At the same time a number of telephone lines were cut off in order to maintain more important lines.

VII. Medical Rescue

On the day the earthquake occurred a rescue team was organized for the injured by the Public Health Bureau. Up until July 31 there had been 61,385 injured that needed treatment (including approximately 20,000 people in Hangu District in Ninghe County), and among them 3,272 were seriously injured who needed to be hospitalized.

To transport medical personnel and medical supplies during the first 3 days after the earthquake more than 120 vehicles were sent out to transport medicine and chemical reagents, medical apparatus and other related materials.

The dead were buried in the suburb after being wrapped in plastic bags. Most of the injured were sent by highway, railway and air to big cities to be hospitalized.

VIII. Repair of Public Buildings

There was a good number of public buildings which were seriously damaged in Tianjin City. In addition, they were located on vital communication routes. Since a secondary disaster might take place moving the operations in time was necessary.

1) No. 1 Cultural Palace

The pinnacle of the front hall tower collapsed and the circular beam on top broke into 5 pieces, some leaned out more than one meter and some weighing more than 10 tons hung upside down in the lift room hanging only by a few steel bars. Two cranes were used to remove the beams. One crane supported workers who tied the cracked reinforced concrete beam to the lift hook of the other crane and then cut off the steel bars and lowered the beam section by section.

2) Tianjin Daily News office

A portion of the roof and wall (5th story) slanted, front eaves of the entrance hall partly collapsed, and the roof of the room was cracked. The inner partition walls below the 4th story were almost entirely cracked. Measures were adopted to support the two ends of the beam with logs from the bottom floor to the 4th floor, and to support the beam end of the top story with piles of sleepers, to divide the reinforced concrete plates of the 5th story into sections and then pick up and remove them. The removal work was finished within 4 days.

3) Navigation protective building

This building was a multi-story structure built with bricks and wood. There was a clock tower which raised over the roof of the top story. The roof of the room was supported by 16 pillars of reinforced concrete. After the earthquake the roof was broken, the pillars were cracked and deformed and a portion of the eaves collapsed. A safety network was set up along the

outside of the eaves, then a scaffold was set up in order to cut off the structural members and to remove them one by one with the crane.

REPAIR AND RECOVERY OF THE DOUHE RESERVOIR

Dong Guangjian[1] and Wang Yuren[2]

The Douhe Reservoir is located in the northeast suburb of Tangshan and was completed in 1956. Its main earth dam was 22 meters high, its up-stream side had slopes of 1:3, 1:5, and the down-stream side had a slope of 1:2.5, 1:4.5. In 1964 an expansion project was carried out and the dam was heightened by 2 meters.

I. General Situation of Damage

The reservoir was about 18 km away from the epicenter of the earthquake but was closer to the causative fault. The level of the reservoir bottom was higher by about 2-3 meters than the surrounding ground. The situation seemed dangerous after the earthquake (see Photos 1-4). The main conditions were:

1) Several longitudinal cracks appeared on both the up-stream side and down-stream side of the earth dam and there were some parts which caved in after the earthquake (for details see the article "Damage to Douhe Reservoir").

2) The earthquake took place during the flood season and it was cloudy and drizzly for days on end. The water level in the reservoir reached 31.64 m in elevation, it was near the spillway; the water level rose continuously at a speed of 1.4 cm/hour and it was only about 2 meters from the longitudinal crack.

3) Strong aftershocks took place one after another. People saw the crevices on the dam open and close repeatedly especially during the 7.1 magnitude shock at nightfall after the big 7.8 shock. This seriously threatened the safety of the dam.

4) No preparations were taken for earthquake relief beforehand. The power supply was suspended when the earthquake took place and the lights and power were all cut off.

Since a large number of cracks appeared and there were no materials and manpower to repair or block them the only solution was to open the water discharge gate and drain the water. To avoid the occurrence of damage caused by draining the water too fast, people were sent out to inspect if any damage was being done down-stream. This way the allowable opening of the gate could be determined.

On July 29, the water discharge gate was lifted manually and water was slowly discharged and it ran smoothly through Tangshan City. This kept the water level at the up-stream side under 32.00 m elevation.

In order to reduce the hazard of overflowing the dam the decision was made to open the gate of the spillway. But because of the quake damage the machines for starting and stopping the

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equipment failed to work. The members of the PLA, who took part in dealing with the emergency, jumped into the engine room in spite of the danger of aftershocks and tried their best to lift the gate. After 6 hours the gate was finally lifted. On July 30, a water conservancy construction team arrived and immediately began to repair the dam. At first they blocked up the longitudinal cracks of the dam and at the same time they drove the piles to prevent sliding at the up-stream side of the dam. In less than 4 days more than 1,800 m of cracks were blocked up and more than 250 piles were driven (Fig. 1), and a large number of sandbags were filled for use in emergencies. On August 4 the dam was repaired and the gate was closed to store water.

II. Overall Repairs

When the repair work on the reservoir was finished the overall repair work on the Douhe Reservoir began to be considered. The post-quake repair work was carried out combined with an enlarged construction plan made before the earthquake and work needed to be finished before next year's flood season. At that time there were a lot of difficulties in immediately repairing the reservoir such as: 1) water storage at the up-stream side needed to be maintained, it was not permitted to empty the reservoir completely; 2) it was much more difficult to repair the damaged reservoir than to build a new one; and 3) because the people suffered from the earthquake there was a shortage of both workers and materials. Of course, there were some advantages such as the information which was provided by the exploration and design for the enlarged reservoir done in 1964 and 1974. Especially helpful was the manpower and material coming from other provinces.

Through exploration the cracks in the dam were deemed to be 3-5 meters deep and after repairing the cracks the 1974 plan for reconstruction of the down-stream slope was put into effect. The work began to first widen the base of the dam, and earth was dug out from the cracks to use for fill on the widened dam. The water level of the reservoir was higher than the bottom of the cracks on the up-stream side and the river channel on the down-stream side needed repair at the same time. Therefore, repair work on the dam had to be carried out in 2 stages. During the first stage the earth was dug out to the bottom of the crack on the down-stream side. In the second stage, when the river channel project on the down-stream side was completed, the water level in the reservoir was lowered below the elevation of the bottom of the crack. The cracked portion of the up-stream side was dug up (Fig. 2). Finally, the dam was built until it reached the designed height.

III. Experiences and Lessons

1. The standards of anti-seismic repair of the reservoir

The very strong intensity that the Douhe Reservoir dam experienced during the earthquake was far beyond its original design. How were the standards of repair to be determined? If the design were to be based on intensity IX to X, it was obvious that the dam thickness would need to be enlarged which would be costey but if the original design was used as a standard in the repair it would be able to withstand the same intensity that occurred in the 1976 earthquake without collapse. Therefore, it was decided that the original standards were to be adopted in the repair.

2. Dealing with emergencies in order of importance

Damage to the Douhe Reservoir was serious and below it was a city with a population of one million people, so the repair was important. The procedure for dealing with this emergency was to learn the nature of the damage quickly and accurately, to pay special attention to the underwater portion of the dam, and to monitor the rising water level. On July 29 the decision was made to lift the gate to drain water and on August 4 the decision was made to close the gate and store water. To drain off water first and then do the repairs was accomplished successfully.

3. Organizing the special contingent in charge of construction

The water conservancy construction contingent had been trained by controlling the Haihe River, and completed emergency repair work in less than eight months. During the repair project 2.8 million m^3 of earth, 0.8 million m^3 of sand and more than 0.2 million m^3 of crushed stones were used.

4. Paying attention to aftershocks while dealing with the emergency

While digging into the sandy soil layer ground face before the drainage equipment was repaired, the original plan to remove sand and soil was replaced by the method of digging pits and filling them with gravel. The layout of the pits was in a plum blossom form with a spacing of 2 meters and the depth of the pits was through the sandy layer (2-2.5 meters). On November 14, the area was submerged by ground water. At that time, it was doubtful that the water permeated only from the upper reaches so when the pit-digging and filling with gravel were completed the filling and covering were not yet made. On November 15 at approximately 9:00 p.m. a magnitude 6.9 earthquake occurred over 50 km away and this made the area ooze water and sand everywhere so a dangerous situation had again occurred. After covering the area with sandbags as rapidly as possible the situation was controlled.

5. Failure in grouting the cracks

There were two plans to treat the cracks at the up-stream slope of the dam. One was to draw down the water level and then do the repairs, the other was to fill the cracks with cement grout while underwater. When the plan to widen and repair the down-stream slope of the earth dam had been completed, it was decided that in order to accelerate the repair process they would utilize the experience gained in the Yellow River Great Embankment project and grout the cracks even though the repair plan of the river channel below the dam was not yet completed. During mid-January a trial of grouting began but the results were not ideal. After having tried several times without success it was decided to lift the gate and draw down the water level to do the repairs. Due to the emergency situation draining off water in large flows was conducted and this caused a large area of land in Fengnan County to be flooded.

The reason for success on the embankment of the Yellow River was mainly because of the silty soil where gradation was bad, the density was low, and the water content was also low. Therefore, the pressure of 2 kg per cm^2 was enough to let mortar seep into the earth and the mortar was absorbed smoothly, and the pressing and densifying action effect were remarkable. But at the Douhe Reservoir the gradation of the dam earth was very good, the density of the soil

was higher and the saturation of the dam reached 90%. In addition, the temperature there was low so that the procedure did not work.

Photo 1. Damage to the upper reaches of the main dam.

Photo 2. Damage to the lower reaches of the main dam.

Photo 3. Damage to the upper reaches of the sub-dam.

Photo 4. Damage to the lower reaches of the sub-dam.

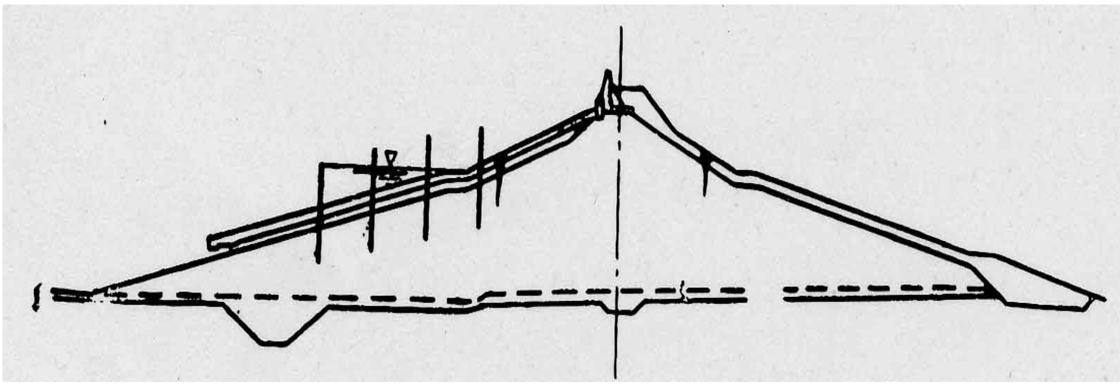

Figure 1. The upper slope of the main dam after repairs on August 3, 1976.

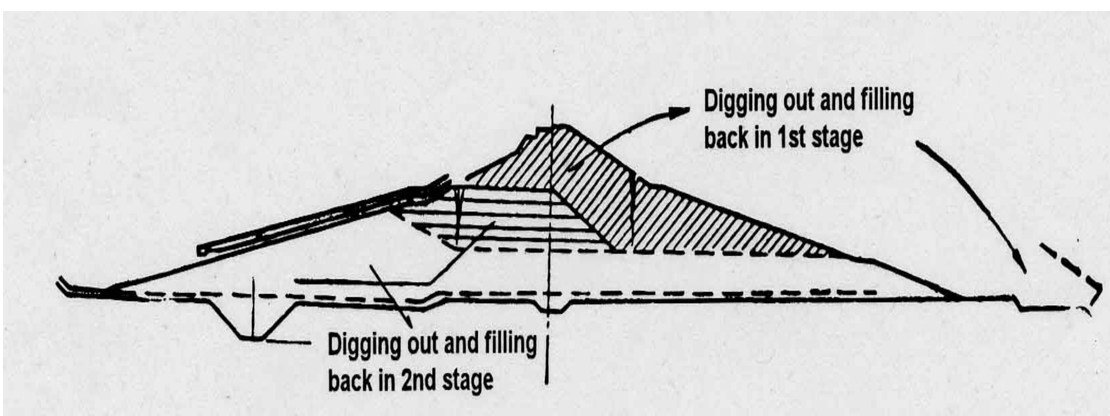

Figure 2. A map of the main dam repaired in stages.

EMERGENCY AT THE BAIHE RIVER MAIN DAM OF THE MIYUN RESERVOIR

Qian Denggao and Zhu Chendong*

The Baihe main dam of the Miyun Reservoir is the biggest and highest earth dam in North China. Its safety is of great importance to the regions below the reservoir, with large populations i.e. Beijing Municipality, Tianjin Municipality and Hebei Province. In 1975 after the Haicheng, Liaoning Province earthquake occurred the earthquake safety of the Miyun Reservoir was of great concern. In order to guarantee the safety of the reservoir the Beijing Municipal Government and the Ministry of Water Conservancy and Electricity studied the problems and organized a Headquarters for dealing with emergencies and specific plans were made.

Before dawn on July 28, 1976 the main dam of the Baihe River was hit by the Tangshan earthquake. A large area of the sand protection layer and the cobblestone protection slope on the up-stream side of the dam slid down. The Headquarters made a decision to: 1) report the situation immediately to the Ministry of Water Conservancy and Electricity and the Party Committee of the Beijing Municipality of CPC; 2) organize manpower to observe the damage at the reservoir and to make preparations to deal with the emergency; and 3) lift the gate to lower the water level in the reservoir.

The leaders of the Ministry of Water Conservancy and Electricity, and the Beijing Municipality, etc., and the engineers and technicians from Qinghua University, the Beijing Municipal Water Conservancy Bureau and other units came to the site immediately to discuss the dangerous situation and the plan for dealing with the emergency.

I. General Survey of Rushing to Deal with the Emergency

According to visual observations the sliding of the slope had taken place near the location of dam pile No. 0+200-0+700 and had a length of about 500 meters. As for the underwater portion of the dam no definite judgment could be made at that time. It rained continuously day after day and aftershocks took place one after another. The damage situation and its development were considered as follows:

1) It was feared that the slope sliding reached to the slanting clay area wall. The clay wall was the essential part, which affected the safety of the earth dam as a whole.

2) The sliding portion of the slope was underwater but the slope above the water level, about 20 meters in height, did not slide; an aftershock might cause it to slide down and expose the clay surface and cause the danger to become more serious.

3) The toppled down portion of the dam's protective layer might slide further down under the action of wind and waves as well as from rain and this might result in collapse.

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* Beijing Municipal Water Conservancy Bureau

4) Flooding might cause the water level in the reservoir to rise and exacerbate the situation. As a result, the work of protecting and dealing with the emergency would be even more difficult.

Through analysis it was deemed that the important part was the section near the water surface. It was also the only part, which could be protected at once. During the earthquake, at the interface between the water surface and the dam body, a steep ridge 2-3 m in height was formed which stabilized the upper part of the slope. Straw bags filled with earth (later filled with gravel) were laid, the reinforced section is shown in Fig. 1. Twig mats were used on the outside of the straw bags to protect them against wind and waves (see Photo 1).

The emergency work was dealt with and carried out rather smoothly and it was basically completed by 6:00 p.m. the day of the earthquake. During the magnitude 7.1 Luanxian County earthquake the dam slope slid down again and the length of slope-sliding was 900 meters long (pile number 0+050-0+950) thus, the workload of dealing with the emergency was greatly increased. There were strong winds and heavy rains at that time. During the night the lighting conditions were poor but after overcoming great difficulties, the project work was basically completed by noon on August 29.

The project handled more than 5,000 cubic meters of earth and stone and, used 200,000 straw bags, 10,000 gunny bags, and 500 pieces of twig mats. The vehicles used in the project included 100 sets of 4-ton automatic dump trucks, 50 sets of 7-10 ton automatic dump trucks and 14 sets of fork lift trucks.

II. Observation of Damage

In order to analyze the damage so as to determine a plan for repair it was necessary to make an inspection and observation of the dam. The following 2 items were done:

1) Routine observation of the dam: observation on settlement, displacement and water level in the pressure-measuring tube, and visual examination of the cracks in the dam slopes.

2) The underwater slope-sliding: especially inspecting possible damage to the clay core wall.

In the first item, because of good organization, the routine observations were completely finished within an hour and a half. The biggest settlement and displacement all occurred within section 0+300-0+500 at the dam top; the biggest was in section 0+400. The settlement amounted to 59 mm, the horizontal displacement to 28 mm and the most serious underwater slope-sliding also took place there. The water level change in the observation tube was approximately 10 cm. At other parts of the dam there were no cracks and no water and sand oozing phenomena were found.

An examination of the local F8 fault was conducted. The fault went through the dam base of the Baihe River main dam and it corresponded to the lower part of the elevation terrace 124 m on the up-stream slope. After the Haicheng (Liaoning Province) earthquake the fault was analyzed and it was deemed that it had the possibility of being active. However, an examination showed that its displacement after the earthquake was less than 0.5 mm and there was no surface trace so it was within normal range. Through the above investigation and analysis it was deemed that the damage suffered by the dam was not yet serious and that no danger of collapse existed.

Inspection and observation of the damage in the slope-sliding area of the dam and the clay slanting wall was a difficult and a complex task. The Headquarters assembled instruments that were suitable to do underwater measuring and used various methods of inspection. These methods included a diving survey; an apparent cross-section method (a kind of transit survey supported by a ship); underwater television (black and white, and color); a general survey and double survey with an echo sounder (including infrared range finding); and a lateral sonar geomorphologic survey (including pulsed laser range finding). At first the diving survey method was used. In only a few days the divers overcame quite a few difficulties and had no regard for danger. They surveyed an area of several 10,000 m^2 and found 5 clay locations (clay slanting wall) within the cross-sections of 0+200, 0+300 and 0+400. Consequently, they practiced the overall survey with key points first by using different methods covering the entire area of the upper part of the dam and its covering and surveyed more than 70 cross-sections. The space between 2 sections was 25 m and 50 m respectively according to the damage degree. Among them a number of key sections were surveyed 6 times repeatedly. The number of unified survey points was more than 1,000, the average point-distance was 7 to 24.6 meters, and the total length surveyed was 20 km. The technical personnel who took part in the survey work came from 19 units all over China.

Through analysis of the survey data it was concluded that the slide on the upper part of the slope of the dam occurred mainly in the gravel portion of the protection layer. In some locations the scratched clay slanting wall was exposed. A few places the clay was softened especially at the sections of pile Nos. 0+300 and 0+425, with an elevation of 120 m and 122.6 m, and the depth of scratches entering into the clay was 0.5 m. Most of the slide was underwater; the elevation of the top was 140-141 m; the elevation of the bottom of the slide was 107 m. The most serious parts of sliding were at the elevation of 120 m or so. The total area of the sliding slope was about 60,000 m^2, and its volume was 150,000 m^3 in total.

Among the survey methods mentioned above each had its own character and only by comprehensively using them could a satisfactory result be achieved. The echo sounder could rapidly provide successive section figures and its operation was simple and it was a better means for measuring depths; underwater TV provided an underwater view of the slide and showed great promise.

Photo 1. Earth slide on the upstream face of the Baihe main dam.

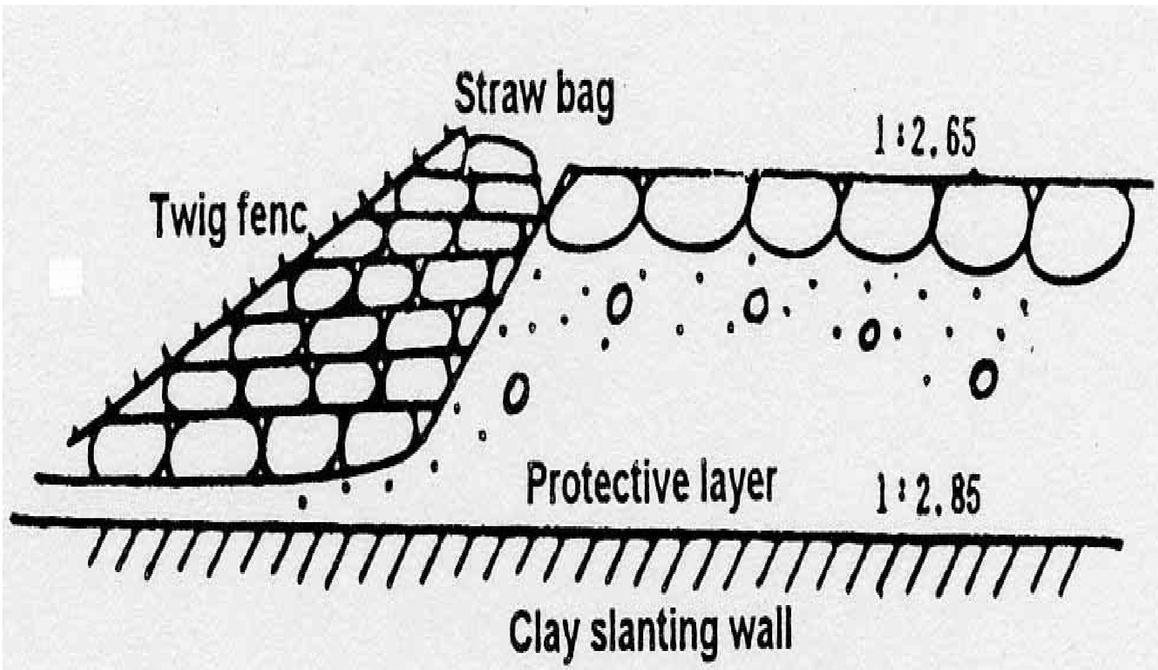

Figure 1. Section of the enforced dam.
Note: (1) straw bag; (2) twig fence; (3) protective layer; (4) clay slanting wall

EMERGENCY REPAIR OF RAILWAY BRIDGES FROM BEIJING TO SHANHAIGUAN

Tang Huancheng and Ding Rao*

During the Tangshan earthquake several bridges on the railway line from Beijing to Shanhaiguan, Hebei Province were damaged and formed obstacles to railway traffic. In order to recover railway transportation the Bridge Engineering Bureau of the Ministry of Railways organized and sent technicians and workers to perform emergency repair and renovation work. The first stage was urgent repair from July 30 to October 10. During that period the emergency repairs on the Ji Canal Bridge and Yongding New River Bridge were completed. This enabled the railway line from Beijing to Shanhaiguan Pass to run on a double-line with limited speed. The second stage of engineering repair began after the trains were running day and night. During this stage one Shimen double-line bridge, one Luanhe River double-line bridge, two Ji Canal single-line bridges and two Yongding New River single-line bridges were repaired. On September 25 the railway line from Beijing to Shanhaiguan returned to normal operation. The following is a description of the emergency repair and recovery of the six bridges mentioned above (except for the Shimen Shahe River Bridge, damage to other bridges is described in Chapter 10 of this book, “Damage to Railway Engineering”).

I. Shimen Shahe River Bridge

The Shimen Shahe River Bridge was built around 1910 as a double-line railway bridge. It is a two-span structure with tracks on top of the bridge. One line is a reinforced concrete beam type, and the other is a riveted steel plate girder which was a replacement built after 1948. The two lines run side by side over the same bridge piers. The bridge is not high; it is only 4.6 m from the base of the pier to its top cap under the steel plate beam. There is a 2 m net gap from the bottom of the beam to the riverbed surface. The load bearing element was originally made of stones in 1953. Under the base of the pier there is a load-bearing element with a height of 1.5 m or so. The pier foundation is wood piles with a diameter of 24 cm, a length of about 6.5 m and a spacing of 82-85 cm. Due to weathering and peeling of the stone surface a layer of concrete with a thickness of 30 cm was applied around each. As there was no connection between the concrete layer and the pier body a crack of 5-15 mm occurred. In 1965 the crack was filled with asphalt and a top cap of reinforced concrete was added. The bridge abutments No. 0 and No. 10 were U-shaped (Fig. 1).

The riverbed was formed from saturated fine silty sand. The sand-shifting phenomenon was serious. The riverbed from pier or abutment No. 2 to No. 10 was protected by laying rubble paving with cement mortar.

There was no damage to the steel girder except for a little displacement. The surface of the lateral partition plate of the reinforced concrete beam end peeled off and the steel bars were exposed due to the beam ends hitting each other.

* Big-Sized Bridge Engineering Bureau, Ministry of Railways

The foundation of the piers all sank. Abutment No. 0 sank the most, 12.5 cm. Some displacement in a lateral direction occurred from pier No. 6 to No. 8. Pier No. 6 displaced 8 cm while pier No. 1 had a longitudinal displacement of 11.3 cm. The double-line beams were relatively different in static weight, a number of pier bodies cracked vertically, the abutment moved toward the center of the river, and the breast wall of the No. 10 abutment cracked from pushing of the beam and the crack was 3 m long. The cone-shaped protection slope and the protection layer in front of the abutment all sank and cracked. The No. 0 abutment was also moved in a longitudinal direction but the distance it moved was not large and the breast wall headed against the end of the reinforced concrete beam.

The protective layer on the riverbed was undamaged, only the joints of cement mortar cracked at the base of the slope. There was ground cracking on the nearby riverbank and there was water and sand oozing on the river bottom above and below the bridge site.

1. Beam structure repaired

Steel girders were moved back to their original positions. The battered and peeling-off portion of the reinforced concrete beam was patched with epoxy resin cement mortar.

2. Bridge abutments

The sunken portions of the bridge abutment and riverbed paving were filled with rubble or ballast to let the water go through at limited speed temporarily. During repairs the cracks of the No. 10 abutment were filled with epoxy resin. In order to stop the abutment from moving while the breast wall of the No. 10 abutment was being repaired, the spaces between the No. 7-10 beams were fully filled to let the earth pressure behind the abutment and the thrust force of the live-load be born by 4 piers, Nos. 6-9 whose beams were abutting. There was no riverbed protection from the No. 0 abutment to pier No. 2 so it was suggested that a layer of stone rubble be placed after the repairs were finished.

3. Piers

There was no protection on the riverbed from the No. 0 abutment to the No. 2 pier. A test pit 3x4x2.85 m was dug near pier No. 1 and it reached the end of the wooden pile. By this time one could see that the subsoil was dense silt. The wooden piles had been used for more than 70 years and they were still in good condition.

Pier Nos. 6-9 of this bridge sustained vertical cracks. Calculation and analysis showed that each half of the double-line pier could carry the load. In order to prevent these cracks from expanding, due to stored up water freezing in winter, they were filled with epoxy resin cement mortar after trimming and chiseling.

II. The Luanhe River Bridge

1. Beam structure

After putting the bridge beam in the original position both laterally and longitudinally, the supports were leveled and the anchor bolts were buried anew. At the same time the broken parts

caused by battering were repaired. Based on past experience with bridge maintenance work beam-moving (small span) could be done without blocking the railway line and by not disconnecting the joints of the rails. Anywhere where the supports were not the same level some dry cement grout was used to do padding which was hardened by the moisture in the air.

2. Bridge abutments

Because the piers were cracked it was estimated that the contact face between the abutment body and the bearing element was also cracked. During the repair ballast was added to the pavement and the trains went through at limited speed.

For permanent repairs a holding-repairing method was adopted. First, the ear wall and breast wall were repaired, then in front of the reinforced concrete abutment supports were made to strengthen the abutment body. The specific way of holding-repairing was to support the railway line behind the abutment with I-beams; one end being supported on temporary sleeper piles and the other end on the terminal part of the steel girder. Digging out back fill of the abutment enabled repairs and rebuilding to be done on abutment and wing walls (Fig. 2). During the holding-repairing period of the Luanhe River Bridge the railway line was blocked for only 38 hours.

Due to the abutment being partly underground the extent of damage was unknown so the examination could only be done by digging out the earth both in front of the abutment and behind it. It was easier to dig out the earth in front of the abutment and a permanent triangular buttress of reinforced concrete was installed. The front end was supported by 2 stakes with a diameter of 1.4 m which were used to do drilling (Fig. 3). The calculations showed that with this arrangement the abutment would be stable under an earthquake intensity of IX. Before digging, in order to prevent the abutment from tilting forward a temporary strut was set up (Fig. 2). The strut was composed of multipurpose shafts and at both ends of the strut hinges were used. From the middle of the strut a level strut was led out to support the middle part of the abutment. A weight cage was set up.

The specific steps of reconstruction were:

1) Assemble slanting strut first and put connecting bolts in place, but not turning them tightly.

2) Lift vertical hoisting jack under the support points of the No. 21 pier to eliminate the bolt clearance then screw the bolts tightly.

3) Loosen the jack to move the parts then hoist again thus shifting the load from the steel beam to the slanting strut. After that the position of the steel plate beam could be adjusted and the bearings could be repaired and trimmed.

4) Dig out the earth in front of the abutment until reaching the level of the support. Then arrange the level strut and the hanging cage whose weight of stone chips was about 45 tons.

5) The level jacks should apply a force of 100 tons each. Then turn the bolts of the level strut tightly.

6) Loosen the level jack between the level strut and abutment body; steel wedges should be inserted and driven in tightly.

7) Dig out earth continuously in front of the abutment until the necessary elevation of the permanent strut is reached.

When the permanent strut is finished the temporary strut should be removed and the sliding slope in front of the abutment should be replaced. All the parts of the permanent strut should be buried in the slope.

3. Piers

The way to contain the cracks in the piers was to install a reinforced concrete hoop. A number of connecting rods were set to join the hoop to the pier body. The thickness of the concrete was determined according to the stress in the hoop section. The hoop's thickness need not be large but a minimum thickness was required to bear the horizontal shear at the cracked section.

III. Ji Canal Bridges

1. Beam structure

After the earthquake most of the fulcrums of the superstructure of the Ji Canal Bridge, except for the middle piers, were displaced and some were off of their supports and all the bridge openings were shortened. The top of the 4 piers which were near the banks of the main span steel trusses of the 2 bridges had moved longitudinally 77.5-204.5 cm. During repairs supplementary struts were added to the middle of the truss end section to form a panel point under which a new support was installed. Meanwhile, the shattered end lateral beam and other damaged parts were repaired and adjusted. The steel girders of the side spans were cut shorter to fit the diminished bridge span.

2. Bridge abutments

Each of the 4 abutments of the Ji Canal Bridges had their own individual problems for damage repair.

1) The No. 0 and No. 6 abutments of the down line bridge had no significant sinking but their longitudinal displacement was bigger, i.e. 1.05 m and 1.52 m respectively; the No. 0 abutment slanted backward with a 3% slope and the steel girder pierced the breast wall. The temporary repair method used was to support the steel girder with a sleeper at the abutment and the ballast and earth under the girder end behind the abutment was removed. Then, another sleeper pile was put up to support the beam end so as to keep trains going through under limited speed. The foundation of the bridge was verified by exploration as being wooden piles. The longitudinal movement of the abutment was caused by the whole riverbank moving. There was no change during one month of railway operating so the permanent repair plan was implemented. The wing wall and breast wall were repaired according to their original dimensions. Between abutment pier No. 0 to No. 3 a 3-span steel beam was set up instead of the original one-span beams to greatly reduce the load on the No. 0 abutment, which was why the breast and wing wall repair

was only returned to the original condition without any strengthening. It was suggested that the maintenance unit make careful observations during later operations. If the abutment were to move any more a chip stone was to be put in front of the abutment to essentially bury it. It was estimated that this measure would not be necessary.

2) The 2 abutments of the up-line bridge settled after the earthquake and the lateral displacement of the steel beam relative to the abutment was bigger. The No. 0 abutment displaced laterally upstream 42.6 cm, sank 70 cm and moved longitudinally 190 cm; the No. 4 abutment displaced laterally upstream 38.5 cm, sank 48 cm and displaced longitudinally 60 cm. The temporary repair method was the same as that used on the down-line bridge. For permanent repairs, except for cutting the beam to accommodate the reduced span length, the other repairs were to offset and raise the top cap of the bridge abutment and the breast and wing walls. For the substructure of the two Ji Canal bridges, except for the exposed part which would actually be measured, other information such as whether it was a whole U-shaped body behind the abutment or a gravity-type with a U-shaped wing wall or whether or not there was a sloped back wall and where the lower limit of the broken section was were all unknown. As trains were running on the up-line bridge it was not possible to dig out the abutment to make measurements so the formwork and the arrangement of the steel bars needed to be made in advance before any digging began and it was necessary to make sure that the repairs being considered could be implemented without delay. Therefore, the formwork was made in advance and the steel bars were arranged so it would not be necessary to make major changes when the work was underway. The shorter the stoppage of trains the better so for repairs they adopted a plan in which lower grade concrete was used in the design but higher grade concrete was actually used in construction mixed with an early strength admixture. In addition, to shorten time both the concrete cap beam and the upper frame beam of the ballast-stop needed to be successful at the first try.

During construction the broken breast and wing walls were removed first then the concrete grouting was completed using a flat form which was made in advance. Connecting rods were used to hold the new and old concrete together. The reason for using a ballast-guard frame beam was that the frame beam could be supported on the abutment body even with a different size below. Besides, its rear beam could act as a pull rod under the condition of thrust from the wing wall ballast live load. The repair was successful.

The No. 4 pier was built according to its design (see Fig. 4). The digging at the No. 0 abutment was at the final stage of the repair of the whole bridge. Time was urgent so there was no time to clear the debris after digging began. The broken and displaced breast and wing walls were left in place and a new breast wall was built in front of the original one forming an L-shaped structure with the newly built top cap which was now elevated. Between the walls stone chips mixed with cement mortar was poured to form a solid body, and on its top a reinforced concrete frame beam for a ballast-stop was built. The repair work project of the No. 0 abutment and No. 4 pier from beginning digging, plan making, formwork and steel erecting to concrete pouring was completed in less than one day.

3. Piers

(1) Down-line bridge

On the bank the No. 1 and No. 2 pier body cracked in a ring shape. Connecting rods and reinforced concrete hoops were built to strengthen them (see Fig. 5 for the hoop arrangement of the No. 1 pier).

The No. 2 pier of the down-line bridge cracked and broke 0.6 m above ground and partially toppled down. When repaired temporarily the steel plate beam was supported by sleeper piles; when the permanent repairs were to be carried out the upper part of the pier body would be grouted anew. As for the No. 4 pier, its main structure did not break seriously so it did not need repair.

(2) Up-line bridge

The No. 2 pier was ring cracked at the upper portion under the bearing of the steel beam. Before repairs divers examined the underwater portion and found no dislocation or cracks so only the upper portion was repaired by adding reinforced concrete hoops.

The No. 3 and No. 5 piers of the down-line bridge and the No. 1 and No. 3 piers of the up-line bridge were located at the slope of the riverbank. The four piers had all moved toward the center of the river. The two piers of the up-line bridge were slanted. The temporary measures taken when doing repairs included supporting the girder beam with I-shaped steel beams and a sleeper pile behind the pier (see Fig. 6) and to let the trains go through at a limited speed.

When permanent repairs were conducted the possible damage to the covered part needed to be investigated. Take the No. 5 pier of the down-line bridge as an example, the pier moved toward the center of the river by 1.76 m while remaining vertical but there could be 3 types of damage:

a) Longitudinal sliding of the whole pier.

b) The first section dislocating from the second section at the pier bottom.

c) The pier body dislocating at higher levels.

The pier was made of rectangular rubble with cement mortar and a coarse surface; the quality of the pier body was good. Cracks often occurred near the ground surface. It was possible that situation "c" above might take place. According to this, the pier body moved 0.97 m and 1.53 m of contact width still remained. Through preliminary calculations it was considered safe for the trains to go through at a limited speed.

There were two repair plans made. One was that the steel beam would remain at the dislocated position after the earthquake and to make the pier body wider the second was to move the support point of the steel beam to the original bearing point. The second plan was decided upon as being more expedient. If the pier body really moved 0.97 m it would not meet the requirements of structural stability so it was necessary to verify the situation.

The first drilling hole went through 0.57 m of stone chips before reaching concrete, at that time it was considered to be a construction wall but when drilling 1 m farther black sandy clay was found. After going through 0.89 m of the sandy clay a piece of wedge-shaped wood about 0.65 m in length was discovered. Further drilling was carried out and a result it was verified that the front edge of the concrete was 1.2 m off horizontally from the pier body top. The second hole drilled was 0.4 m from the first hole toward the center of the river and at the same depth as the first hole where the concrete was found the thickness of the concrete layer was 0.93 m. Passing through the concrete the drilling reached the wood immediately; the wood was cylinder shaped with a sharp edge and was 1.05 m in length. Under the wood there was again black sandy clay. The wood shape determined from the 2 holes is shown in Fig. 7. The second piece of wood, where of its sharp edge changed to 90°, had a length, which was parallel to the drilling hole. The appearance of the second wood piece further indicated that a wood pile foundation existed. For its possible arrangement see Fig. 8. The third drill hole was 0.8 m from the first and second holes at the lower reaches and 0.42 m from the top side of the pier body. Neither wood piles nor concrete walls were found.

Inferring that the slanting pile inclined towards the bank and that it was a square pile as used in the past, the pile could move 0.3 meters and the center distance was about 0.8 m. There should be one straight pile at 0.4 m to the right or left of the center line of the bridge. The position of the No. 4 drilling hole was determined here. The result was as expected, a straight pile with a length of 1.1 m was found. At the same time, wood piles were also discovered both in a drill hole of the No. 3 pier and in another drill hole in front of the No. 0 abutment. Therefore it was concluded that all pile-foundations were made completely different from the original report on the pier foundations. The restored No. 5 pier foundation is shown in Figure 9. The length of the piles were 16-20 m and there were both straight piles and slanting ones. This showed that the ground fissures on the riverbanks parallel to the river made both the riverbed and the piles move as a single body so that the repair plan of shifting steel beam support points was adopted.

The main problems of the up-bridge were at the No. 1 pier. An examination using hole-drilling was adopted. The hole-drilling position is shown in Fig. 10. The results showed that the foundation of the No. 1 pier was a sunk-well, the depth of which was 8.9 m or so (original data was 16.5 m in the archives). The repair to the No. 1 pier of the up-bridge is shown in Fig. 11. The repaired up and down-bridges are shown in Fig. 12.

IV. The New Yongding River Bridge

To deal with ice-floating problems during the winter it was decided to build a new bridge. Therefore, for this bridge only a temporary repair plan was considered.

1. Beam structure

The beam dislocation was corrected either in a longitudinal or in a lateral direction. The bearing was adjusted and the anchor was buried anew. In addition, all the damaged parts caused by being hit were fitted.

2. Abutment

The crevices of the abutment were filled with epoxy resin by a press-grouting method. The place where the beam headed against the abutment was chiseled off but when the No. 20 abutment of the up-bridge was chiseled off the abutment immediately moved against the beam with no ill effect so the chiseling stopped. Instead, an auxiliary pier made of concrete chunks was built in front of the abutment to stabilize it (Fig. 13). Observing it for a long time the beam still pressed against the abutment but no problem resulted.

3. Pier

The bridge is temporary, no overhaul is needed.

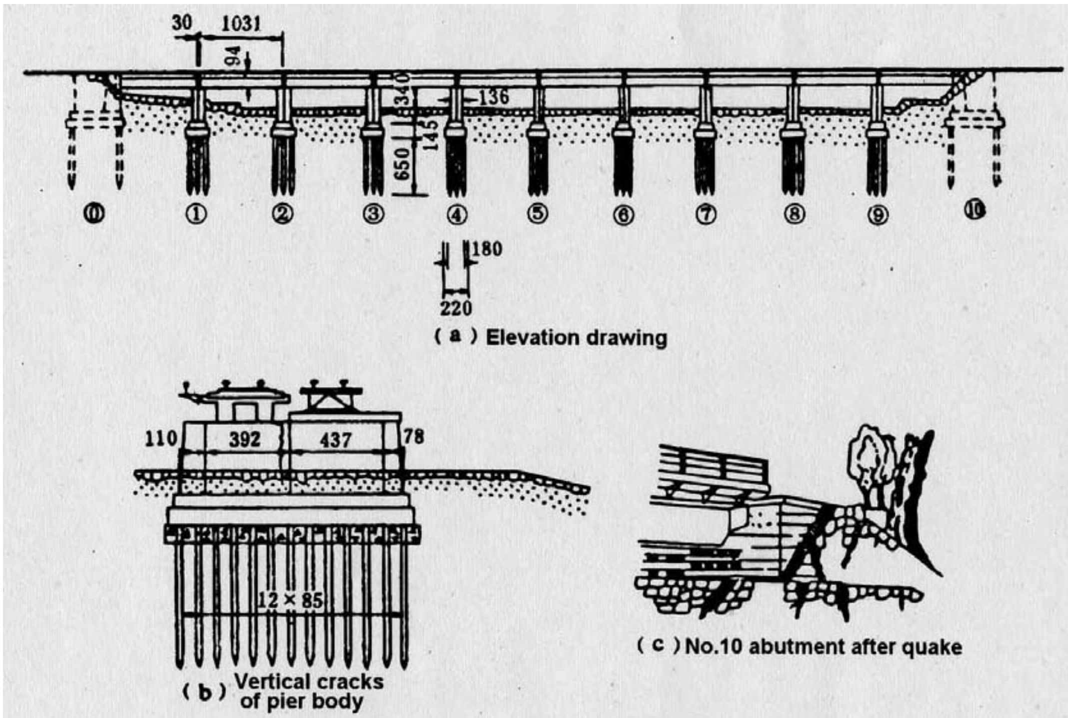

Figure 1. A sketch of the Shiman Shahe River Bridge (unit: cm).

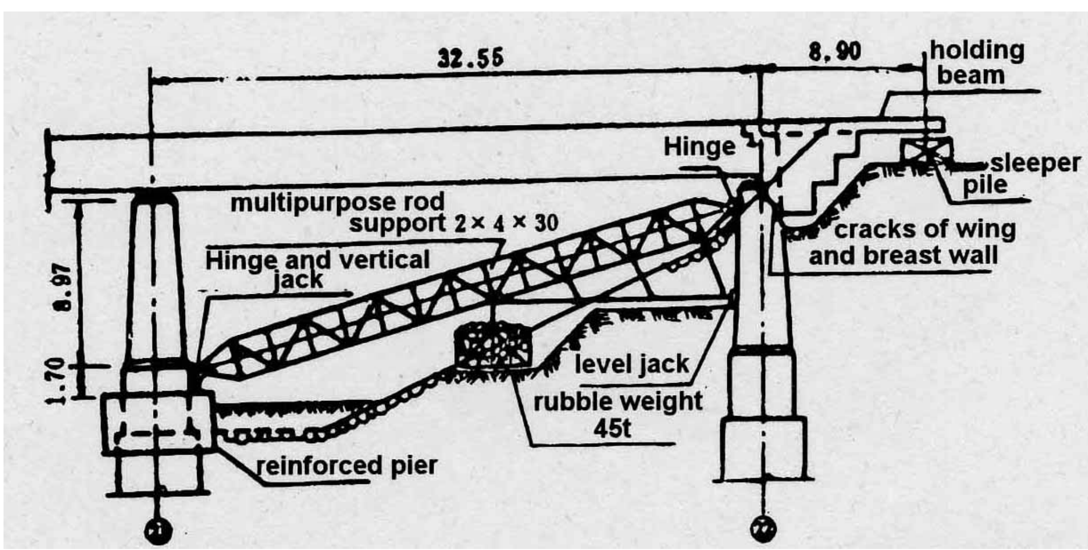

Figure 2. A sketch of the repairs of the abutment of the Luanhe River Bridge and the temporary support (unit: m).

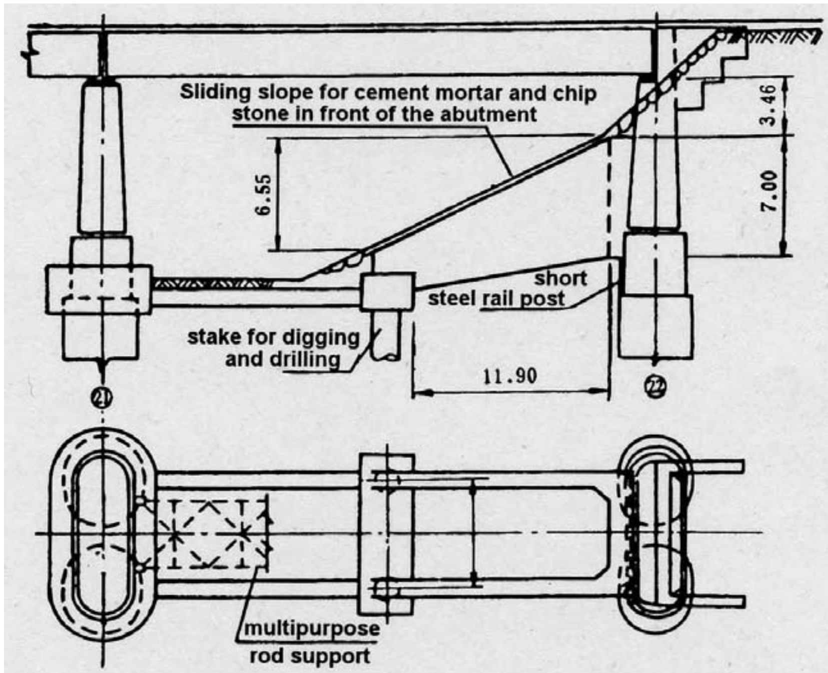

Figure 3. A sketch of the permanent repair of the abutment of the Luanhe River Bridge.

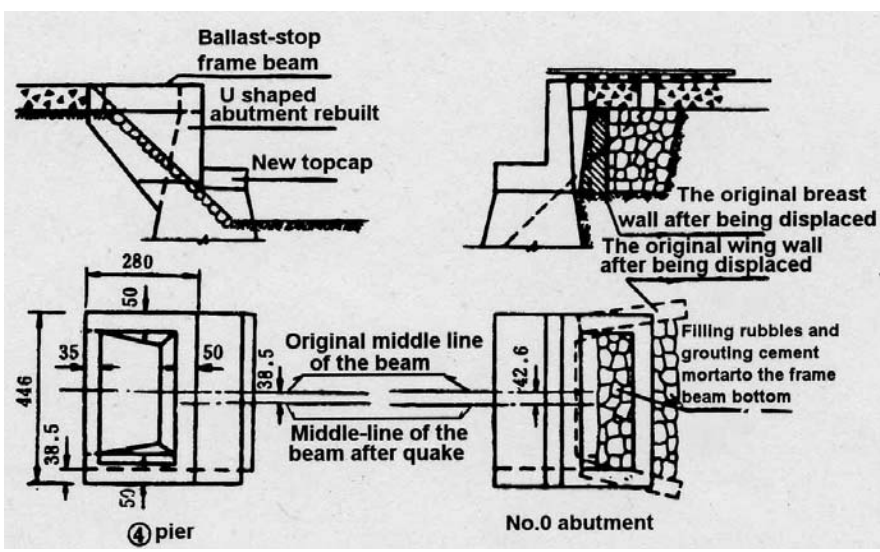

Figure 4. Abutment repair sketch of the Ji Canal up-line bridge (unit: cm).

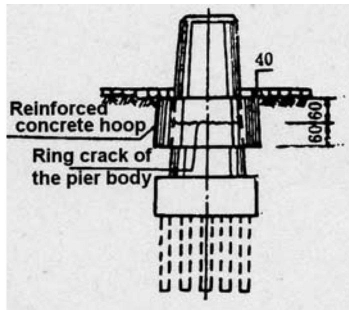

Figure 5. Reinforced concrete hoop of the No. 1 pier of the Ji Canal down-line bridge on (unit: cm).

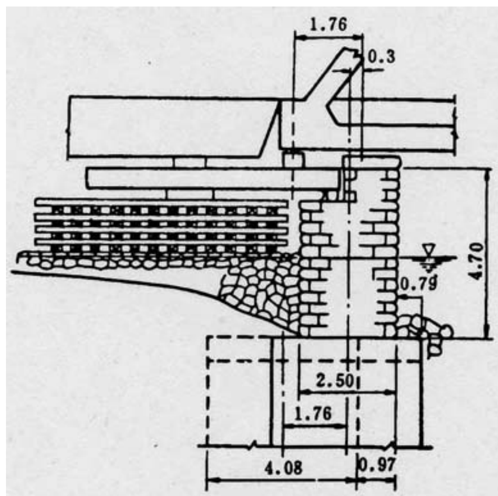

Figure 6. Sketch of the dislocated and temporarily repaired No. 5 pier of the Ji Canal down-line bridge (unit: m).

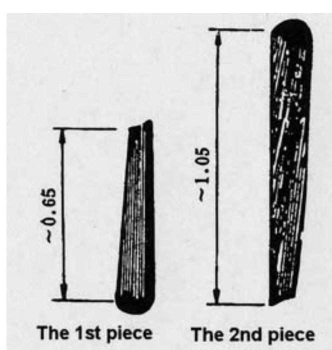

Figure 7. Wood pile samples from a drilling hole at the No. 5 pier of the Ji Canal down-line bridge (unit: m).

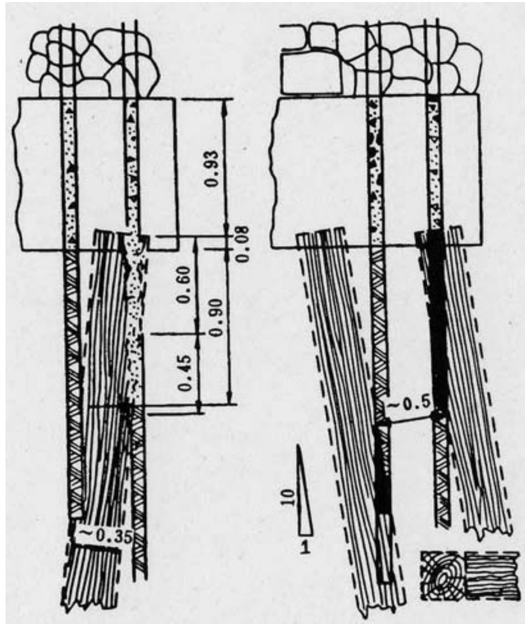

Figure 8. The possible position of the slanting pile at the No. 5 pier of the Ji Canal down-line bridge (unit: m).

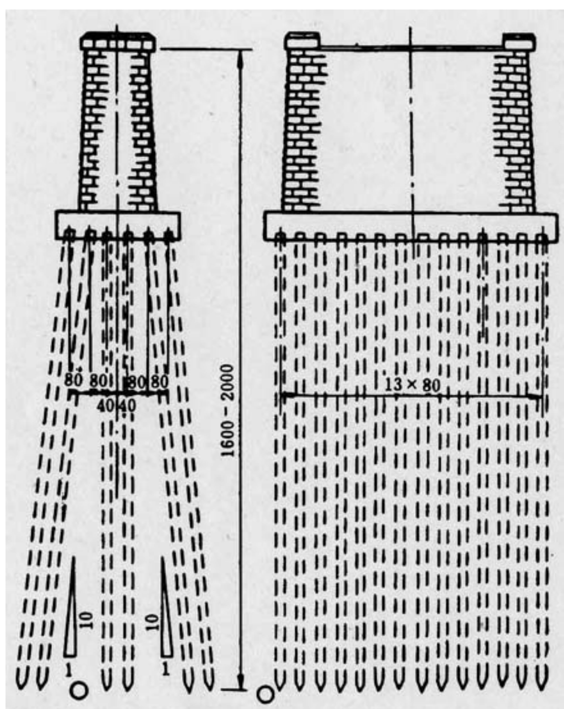

Figure 9. The inferred pile arrangement at the No. 5 pier of the down-line bridge (unit: cm).

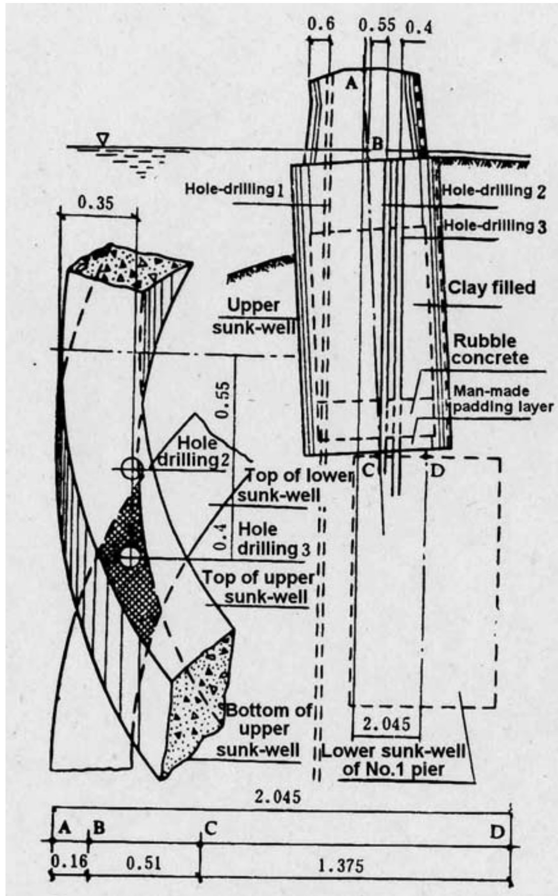

Figure 10. Layout of the No. 1 pier hole-drilling of the up-line bridge (unit: m).

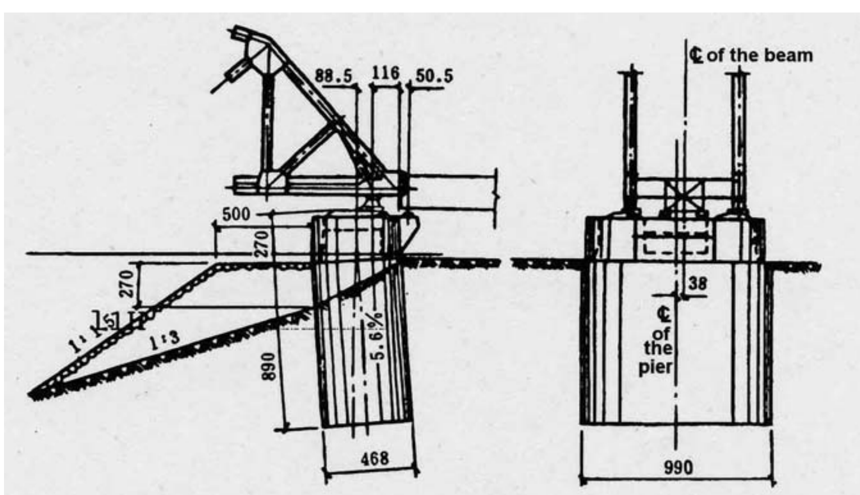

Figure 11. A sketch of the repaired No. 1 pier of the up-line bridge (unit: cm).

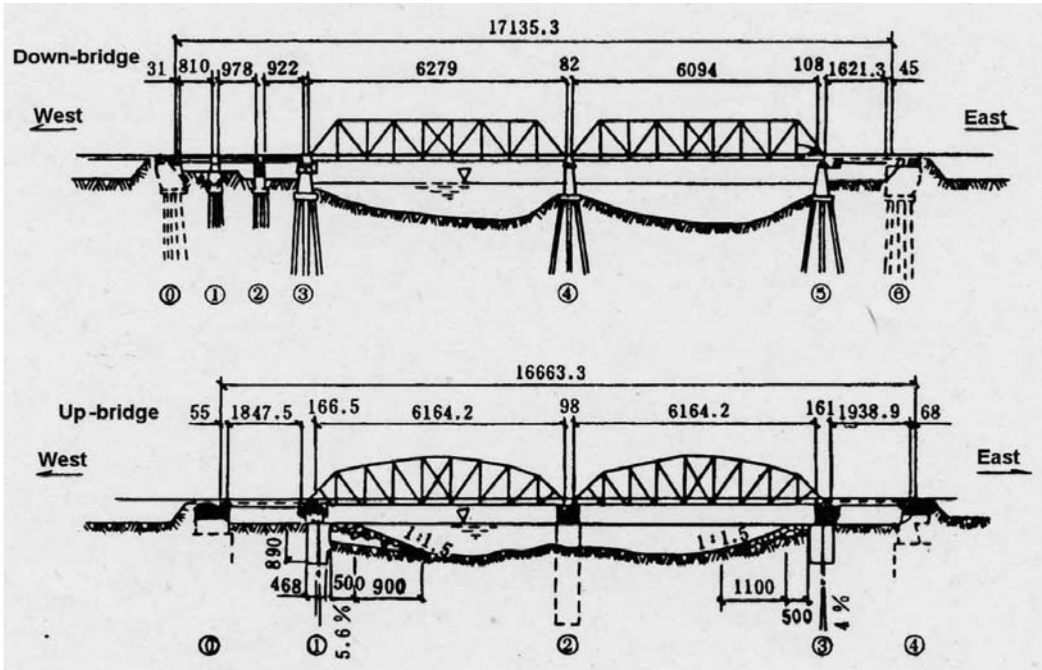

Figure 12. Ji Canal up-line and down-line bridges after being repaired (unit: cm).

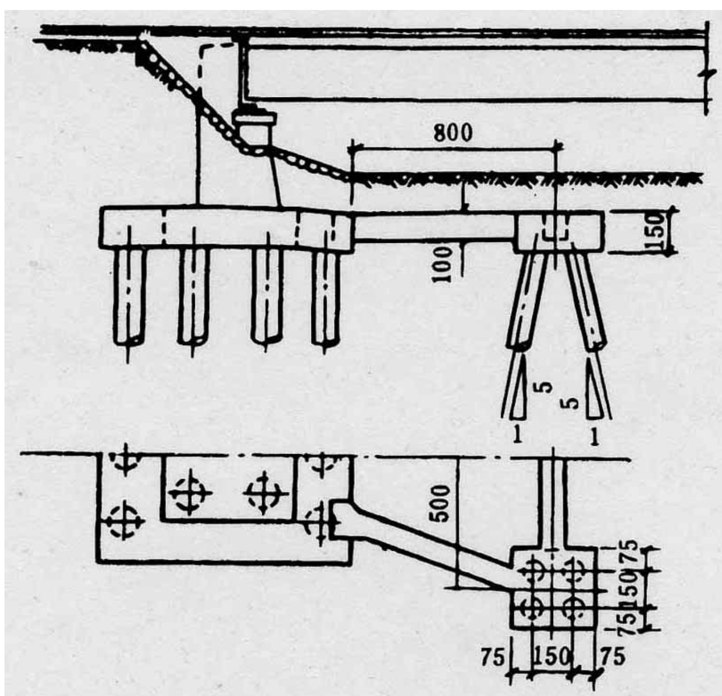

Figure 13. Bracing struts at the abutment of the new Yongding River Bridge (unit: cm).

REPAIR OF HIGHWAYS AND RELIEF TRANSPORTATION

Xu Fengyun,[1] Liu Jingsheng[2] and Yin Longsen[2]

I. General Introduction to Repair

After the Tangshan earthquake all the highways in the Tangshan Prefecture were damaged. In order to recover traffic as soon as possible and fulfill the task of transporting disaster relief materials the Ministry of Communications, following the State Council's instructions, immediately established a command system for emergency repair. People were sent to investigate the condition of damaged highways; bridges and traffic blockages and plans were made. More than 104,000 people were assembled at once from construction units, transportation units, public security forces, engineer corps of the PLA and from nearby villages to take part in the repairs and traffic control. On the morning of August 5 all six main highways to Tangshan were reopened to traffic. Each day about 10,000 vehicles drove to Tangshan. In August and September 4,785 automobiles and 1,328 trailers from the communication units were put into operation transporting 1.8 million tons of disaster relief goods, building materials and a large number of injured and sick people.

The assembled forces were assigned to repair bridges first. Many different repair measures were taken due to topography, width and depth of the rivers and the difficulty of repair. For example, temporary floating bridges were set up, pre-assembled steel highway bridges were installed, temporary wooden bridges were put up, rail-sleepers were laid, and old bridges were reinforced or a new detour line was built, etc.

At 7:00 p.m. on July 29, the Ninghe Boat Bridge was completed. That was the beginning of reopening the Tianjin-Tangshan Highway to traffic. On August 2, the Luanhe Boat Bridge was finished and the Shanhaiguan-Tangshan Highway was reopened to traffic. Afterwards, some temporary highway steel bridges and wooden bridges were erected. By the 5th of August all six main highways to Tangshan were unimpeded. Table 1 shows the date of reopening of the main bridges and highways to traffic and the units in charge of the construction.

The following is the course used to repair Shengli Bridge in Tangshan and Lutai Bridge in Ninghe County.

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I) Erecting the Shengli temporary steel bridge in Tangshan

1. Scheme selected

Considering the topography of the bridge site, the depth of water and the requirement for application it was decided that two pre-assembled steel highway bridges should be built on the former location of the bridge so vehicles could travel in two directions.

The two bridges having the same structure type were 2 m apart in net distance. The load standard was truck Grade 10. The vehicle lane was 3.7 m wide. The riverbed was only 50 m wide but the new bridge was designed to be 72 m long in consideration of the continuous embankment slides and the crack along the bank after the earthquake. The bridge had three spans. The span near Tangshan was 18 m, the middle span was 30 m and the one near Luanxian County was 24 m. Figure 1 and Photo 1 show the layout of the steel trusses.

For fear that the piers might sink unevenly the three spans were all simply supported girders. The components and tools used in the construction of each bridge are shown in Table 2 and Table 3.

2. Pier construction

The net height was about 4-5 m under the bridge; 2 wood-cage piers were adopted.

The cages were made of logs which were 20 cm in diameter. The logs were fixed with bolts and #8 wire with stone-retaining boards around the cage.

When they were fixed the cages as well as the surrounding area of the bases of the cages were filled with flat stones to one-third of the height of the cages. Then, 6 wooden lattice beds were laid on the cage pier to support the seat plate of the steel bridge.

3. Assembly and erection

1) Arrangement for the assembly site

The assembly site was carefully selected before the assembly work was to begin. All the components were placed in order on both sides of the work site. The site was carefully leveled to ensure assembly quality.

2) Assembly

Two kinds of rollers were laid on the assembly site, a rocking roller and a flat roller. Flat rollers were used to assemble and move steel trusses. There was a set of these rollers every 6 meters along the bridge axis. Rocking rollers were set on both banks to ensure the end posts would be seated on the central line of the seat plate accurately when the bridge girder took its final place. The elevation of the rocking rollers needed to be accurate.

When the girder truss was lifted up to the pier a guide beam was temporarily placed at the front end of the truss in order to reduce the weight of the cantilever. The guide beam was made

up of three sections of a single-row truss (truss, transverse girder and wind bracing). The guide beam was dismantled after the project was completed.

During installation the guide beam was first, then all the truss sections were assembled in proper order. Only the sectional truss, girder and wind bracing were assembled at the site. Longitudinal girders, bridge deck plates and other accessory components were to be assembled after the truss girder was lifted up onto the piers. The following experience was gained from the assembly.

a) Transverse-girder clamps and wind bracings should not be tightly fastened on the girder until the transverse girder, diagonal members, truss and link boards are in place.

b) During assembly make adjustments to keep the truss in alignment. Be sure that no bending appears. Much attention must be paid to the tension and length of wind bracing.

c) Whenever there is difficulty in attaching any of the components try to find the cause and loosen some clamps and adjust them. Never apply force on them to avoid any damage.

3) Lifting the truss up onto the piers and installation

The assembled trusses were lifted up onto the piers manually. Since the assembly site was rather small some prop stands were put up under the end of the smaller span on the bank in Luanxian County.

The girder truss was lifted after it was assembled. All the people who took part in lifting the truss moved together to avoid any distortion.

When the middle span of the first steel bridge of Shengli Bridge was erected the maximum deflection of the cantilever was 70 cm so a V-shaped boom was put up over the wooden cage pier with a hoist. When the cantilever reached the edge of the pier it was lifted by the hoist. During lifting of the second steel bridge another method was adopted. Before lifting, the fulcrum on the bank was set up higher so that the end of the cantilever was slightly higher than the top of the pier to ensure the guide beam would move onto the pier smoothly.

After erecting the bridge the fulcrum on the bank was lifted by jacks. Rollers and spacers were removed so that the steel trusses were seated on the bearing plate. Meanwhile, end posts, longitudinal girders and the bridge deck were installed. Then, the guide beam at the front of the girder truss was removed. Finally, all the nuts, pins and screws were carefully checked to make sure it was safe for use.

4) Effect

It took three days to build the first Shengli Bridge (including the construction of the wood caged piers) and two days to build the second Shengli Steel Bridge. Each cost 4,000 worker-days (including not only the construction of the bridge itself but also transportation, loading, unloading and a period of maintenance after the bridges were completed). The building cost per meter of the bridge averaged 575 RMB yuan (including the cost of the wooden cage piers, but not including the cost and transportation charge of the steel bridge components). It was

convenient to build such bridges and took a shorter period of time. They were in good condition all the time; there was dense traffic during the period of earthquake relief.

II) The repair of Lutai Bridge

This was a 3-span main bridge plus smaller 3-span bridges at each bank; the total length was 168 m. During the earthquake the main span and the second span from Tianjin bank fell into the river and traffic on the Jin-Yu Highway was blocked.

1. The repair plan

After surveying the conditions a plan was made to erect a typical pre-assembled highway steel bridge on the piers. The main ideas of the plan follow:

1) Even though the piers cracked in several places they did not settle much and the slant angle was small and the loading capacity was not reduced much. They could be temporarily used.

2) In the middle section a pre-assembled steel bridge having three rows of girders with reinforced chord members was adopted forming a continuous girder of three spans with a length of 21+54+21=96 m. The positive moment and deflection of the middle span was reduced by the continuity.

3) In the sections at both ends steel bridges having three rows of girders with reinforced chord members also adopted forming continuous girder with three spans 8+20+8=36 m.

4) At the Lutai end the ground was leveled and there was a straight section of about 350 m. The slope angle was small (about 1%) and there were no roads across it so it was selected as the assembly site.

5) The superstructure was made up of an assembled truss with 56 panels of 3 m. The total length was 168 m. In order to save time the work started at several places at the same time. At the work site the superstructure was assembled into a three-row single layer structure of 168 m with reinforced chords. The longitudinal and transverse girders and the deck were ready. It was then lifted into place at one time after checking it.

6) After the whole bridge was lifted to its place the connectors of fulcrums 3 and 5 were removed, dividing the bridge into three independent sections: 36+96+36 m.

7) The upper three rows of the middle section were installed after the bridge was in place so as to reduce the weight when lifting.

2. Erecting the superstructure

When the bridge was assembled it weighed as much as 300 tons. The following problems had to be solved while lifting and erecting.

1) The main span was supported by a floating pier

Between piers 4 and 5 a temporary floating pier was put up so as to shorten the cantilever to 27 m during installation. The floating pier was made up of two 60-70 ton boats with wood piles on them. On the top of the wood piles there were rocking rollers forming floating piers. The floating piers, fixed by anchors on each side, were a little lower than the previous bridge deck. Photo 2 shows the floating piers, floating boats and the assembly scene.

2) Towing and rolling apparatus

While lifting there was a rocking roller and a flat roller at every second panel point. The weight of the rocking roller was 25 tons and that of the flat roller was 6 tons. The friction coefficient between the steel girder and the rocking roller or the flat roller was estimated to be 0.07 so the traction force was about 21 tons. On both sides there were 5 tons of single roller electric hoists with 3-4 pulley groups. See Photo 3 for the scene of steel girder towing.

3) Controlling the stability while moving and lifting the bridge

The bridge was completed by a single assembly so the stabilizing moment was bigger than the overturning moment all the time. Because it was pulled by electric hoists with groups of pulleys it moved slowly and steadily. During towing some safety measures were taken such as demanding that the workers pay great attention to the upper part of the structure and adjust it if it inclined. When it was towed to the pier the end of the upper part of the structure drooped. When it almost reached the pier a large deflection appeared so a support was put up for assembly before it was towed out so that the height of the raised end would be the same as the deflection.

4) After the steel bridge was towed into place it was divided into three simple supported girder sections

A group of pulleys were set up on the steel bridge so that the assembled girder truss could be hoisted into place on top of pier 4 and pier 5. The rocker bearings were fixed then the steel bridge was lowered and leveled. A single layer woodpile was set up for every other support. Finally, it was connected with the approach spans. Taking into consideration the possibility of aftershocks and in order to avoid distortion the bridge was braced with cables. Then, the transverse girder and the bearing plates on pier 4 and pier 5 were welded together. The transverse girder was tied firmly to the piers with wire rope to avoid falling or displacement. After the connections the bridge could be opened to traffic if the deflection of the middle span was less than the allowable value and no obvious distortion was seen in the bolts of each component. Photo 4 is the erected bridge in place.

The rods, parts and tools used on the bridge are listed in Table 4 and Table 5.

II. Traffic Administration

After the earthquake a large number of vehicles were concentrated in Tangshan. The traffic was in a state of confusion which impeded the transportation for earthquake relief. Therefore, the Earthquake Relief Headquarters issued an “Announcement about strengthening the Traffic Administration in the Beijing-Tianjin-Tangshan Region” on July 30 and on July 31 the Ministry

of Public Security and the Ministry of Communications established the Traffic Headquarters. The Headquarters was in charge of traffic control, traffic order and traffic coordination.

Traffic directing stations were set up at major crossings along the main highways between Tangshan and Tianjin. Traffic personnel were on patrol duty day and night to keep the traffic in order. A traffic command office was set up for each of the three main highways to Tangshan. There were 180 traffic directing stations and more than 3,000 traffic directing personnel including 1,100 PLA officers and men, 380 policemen, 30 traffic administrators and more than 1,500 militiamen from communes. There were 432 traffic signs that were placed at main crossroads, ferries and bridges.

Ninghe Bridge and Luanhe Bridge were on key traffic lines between Tianjin-Tangshan and Tangshan-Shanhaiguan, respectively. Army units guarded them and directed the traffic. Before the second line (double line) was built they alternated one-way traffic on the single-line. After the double lines were completed each of them was for one-way traffic.

With the enhancement of traffic control and the recovery of highway construction the highway transportation became normal step by step.

Table 6 shows the traffic volume at a few main traffic spots after recovery of traffic.

Table 1. Statistical table for repairing the main bridges and reopening them to traffic.

Bridge	Line	Length (m)	Span (m)	Method of Repair	Unit in Charge	Reopening Time
Ninghe Bridge of Lutai	Tianjin-Tangshan	169.5	main span 54 m	military boat bridge	Engineer Corps of the PLA	19:00 July 29
				highway steel bridge	No. 1 Bureau, Ministry of Communications	24:00 Aug. 3
Luanhe Bridge of Luanxian	Shanhaiguan-Tangshan	789	22.2	military wooden bridge	PLA troop	Aug. 2
				temporary wooden bridge	PLA troop	
				reinforced previous bridge	Provincial Bureau of Hebei	Aug. 11
Leizhuang Bridge	Shanhaiguan-Tangshan	217.78	11.4	railway tracks and sleeper piles	No. 1 Bureau, Ministry of Communications	6:00 Aug. 2
Shengli Bridge	Tangshan suburb	55	11.0	double steel bridge	No. 1 Bureau, Ministry of Communications	single line: 18:00 Aug. 2
						double line: 24:00 Aug.
Xiazhuang Bridge	Tangshan suburb	44	11.0	C	a unit from construction Engineer Corps	July 29

Table 2. The quantity of components and materials of the Shengli temporary steel bridges (for each bridge).

Item	Order No.	Name	Unit	Quantity
assembly components and parts	1	truss	piece	232
	2	transverse girder	piece	102
	3	transverse girder clampers	piece	464
	4	threaded longitudinal girder	piece	96
	5	non-threaded longitudinal girder	piece	144
	6	positive end post	piece	28
	7	negative end post	piece	28
	8	diagonal member	piece	96
	9	strut	piece	96
	10	link board	piece	96
	11	wind bracing	piece	96
	12	bridge deck	piece	640
	13	protecting log	piece	96
	14	bridge seat	block	47
	15	seat plate	block	20
	16	pin	piece	520
	17	flat roller	piece	6
	18	different bolts	piece	1168
main material	1	stone	m^3	350
	2	wood	m^3	76.8

Table 3. The main mechanical equipment used for erecting each bridge.

Series No.	Item	Unit	Quantity
1	30KVA welder	set-shift	13
2	75KV generator	set-shift	14, for illumination
3	8-ton lorry	set-shift	14
4	4-ton Jiefang lorry	set-shift	96
5	8-ton crane	set-shift	48

Table 4. Main members of the Lutai (temporary) Bridge.

Name of Member	Unit	Quantity	Installation Location		
			Middle Section	Two End Sections	Embankments at Two Ends
steel truss	piece	528	384	144	
reinforced chord	piece	528	384	144	
truss pin (including rod pin)	piece	1740	1140	600	
truss bolt	piece	384	384		
chord bolt	piece	1344	768	576	
transverse girder	piece	115	65	50	
clamps for transverse girder	piece	676	388	288	20
threaded longitudinal girder	piece	132	64	48	20
non-threaded longitudinal girder	piece	132	64	48	20
positive end post	piece	6		6	
negative end post	piece	6		6	
diagonal	piece	112	66	52	
support	piece	178	130	48	
link plate	piece	180	128	52	
support bolt	piece	1308	908	400	
wind bracing	piece	112	64	48	
deck	piece	1140	480	360	300
wood curbs	piece	152	64	48	40
rocking roller (including seat)	set	6	6		
bolt for wood curbs	piece	608	256	192	160
$^{\#}$65 I-steel	m/piece	40/4	40/4		
15 mm steel plate	m^2	10	10		

Table 5. Machines and tools used in the construction of the Lutai (temporary) Bridge.

Name	Specification	Unit	Quantity	Remarks
crane	5-t truck	set	2	for unloading and assembly
crane	500 kg	set	1	to assemble steel girder
hoist	5-t single drum electric	set	2	for towing girder
generator	50-70 kw	set	2	for light and dynamic power
wire rope		km	3	for towing girder
jack	hydraulic 300	set	30	for lifting girder
flat roller		set	30	special for laying girder
rocking roller	(including seat)	set	40	
English wrench	12°-18"	pair	40	
different spanners	special for moving girders	set	20	
wooden boat	60-70 tons		2	floating boat
tug			1	carrying tools on the river
tarred sleeper	railway repairing sleeper	piece	1500	wood pile for floating pier, approach wood pile and the pile at disconnecting spot
fir pole		piece	30	for temporary scaffolding
scaffolding board		m	3	
electric welder		set	2	welding the I-steel and transverse girder

Table 6. Traffic volume statistics at main traffic locations.

Date	Place	Line	Traffic Volume (vehicles/day)
August 8	Ninghe Bridge, entrance to Tangshan	Tianjin-Tangshan, into Tangshan City	2,500 6,000
August 10	Ninghe Bridge, Yutian	Tianjin-Tangshan Baodi-Yutian-Tangshan	3,400 2,700
August 16	Ninghe Bridge, Luanhe Bridge	Tianjin-Tangshan Shanhaiguan-Tangshan	2,142 6,132
August 18	Tongxian, Tongxian, Ninghe Bridge, Luanhe Bridge	Beijing-Tongxian-Tangshan, Beijing-Tianjin, Tianjin-Tangshan, Shanhaiguan-Tangshan	1,226 2,235 2,385 4,503
August 20	Tongxian, Ninghe Bridge, Luanhe Bridge	Beijing-Tongxian-Tangshan Tianjin-Tangshan Shanhaiguan-Tangshan	1,450 2,500 5,000
September 9	Tongxian, Ninghe Bridge, Luanhe Bridge	Beijing-Tongxian-Tangshan Tianjin-Tangshan Shanhaiguan-Tangshan	1,200 3,000 5,000

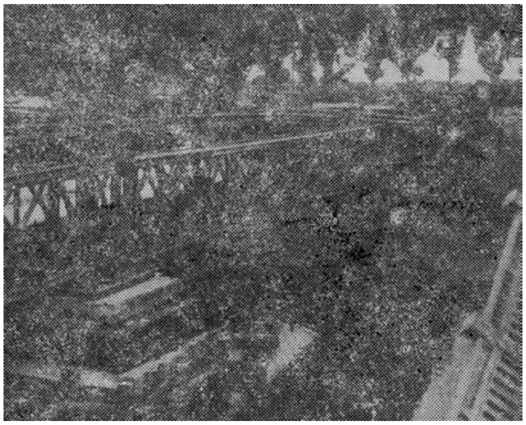

Photo 1. The Shengli Steel Bridge.

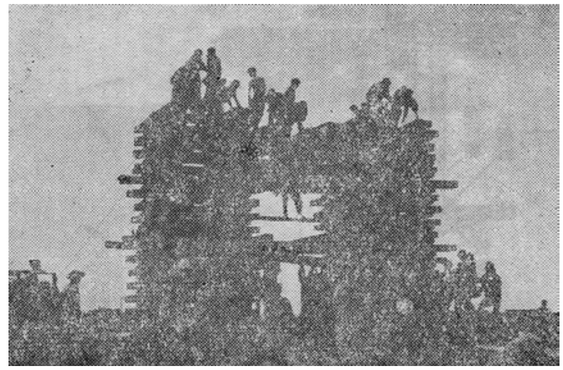

Photo 2. Wood was piled on linked boats to build floating piers.

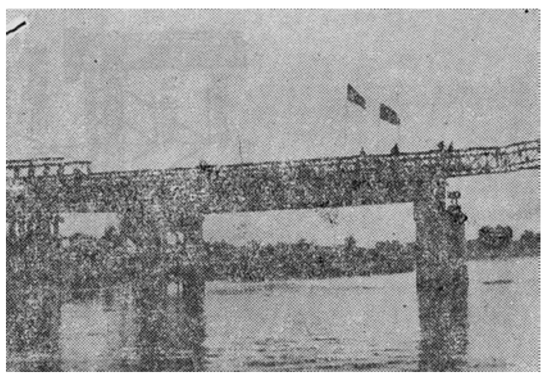

Photo 3. Towing the simple steel bridge into place.

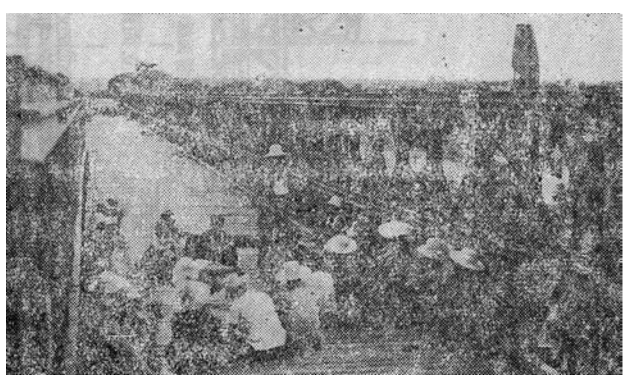

Photo 4. The finished Lutai Steel Bridge.

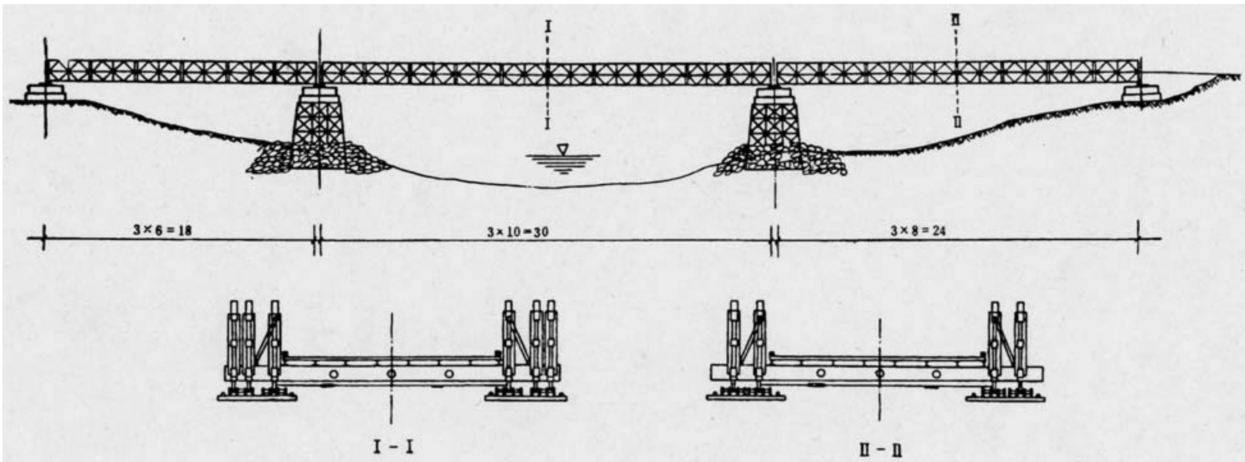

Figure 1. The temporary steel structure of the Shengli Bridge (unit: m).

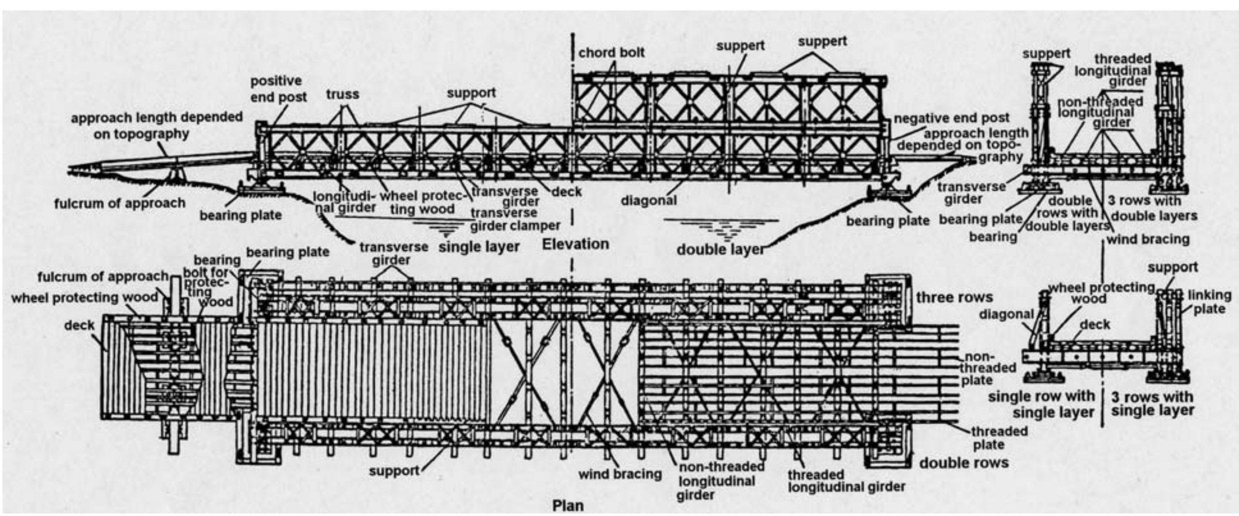

Figure 2. The simple steel bridge adopted to repair the Lutai Bridge.

Repair of the Tangshan Municipal Water Supply System and Recovery of the Water Supply

Shen Ersong*

The Tangshan earthquake seriously damaged the water system in Tangshan City and water supply in the urban area was disrupted. After repairs clean water from deep wells was delivered to most of the area only five days after the earthquake. Two months later the repair work on the main water supply pipe system was completed and covered 70% of the area serviced before the earthquake. The essential water supply was recovered.

The measures taken for repair are as follows:

1. An immediate inspection was made of damage to water facilities, especially damage to the macrostructure. Repair work was planned. Meanwhile, the outlet control valves were turned off as soon as possible to avoid any harm caused by water.

2. The first thing to do was to recover the water source after damage was ascertained, i.e. to recover new pressure wells and water sources from wells whose second stage pumping houses were not damaged. After the water sources were recovered the broken underground pipe network was located and was repaired. Temporary pumps and pipes delivered water to nearby areas. Also, eight slightly damaged wells of some enterprises were repaired and began to supply water.

3. To avoid any abuse or pollution armed militiamen were sent to guard the two clean water reservoirs whose storage was about 6,000 m^3 each. Fire engines took water to medical units, emergency hospitals, etc. which badly needed water.

4. The authorities concerned got in touch with the Electric Power Supply Bureau and asked it to go all out to resume supplying power to the water source wells and water works that were not badly damaged. The water supply department thoroughly checked and regulated its own internal electric lines and equipment, getting ready for power resumption. The undamaged high voltage distributing cubicles (10 kv and 6 kv) for the water supply system were repaired and regulated promptly for power consumption. The Power Supply Bureau added a switch cubicle to supply power directly to the transformer of the water works by passing the switch cubicle damaged by the collapsed buildings. Part of the water system was supplied with power only four days after the earthquake.

5. Before the pipe network (especially the main outlet pipes of the water works and relay pressure well) was recovered, water from standby pressure wells and enterprise wells was delivered through ϕ50 mm open hoses from the fire brigade with temporary pumps fixed on the roofs of the clean water reservoirs. During the 20 days after the earthquake 11,000 m of hoses (transported in by air) were laid and appointed persons were in charge of patrol and maintenance.

* Tangshan Municipal Construction Bureau

Water was delivered as far as 2 km through fire hoses. The earthquake relief command office utilized fire engines and sprinklers to send water to farther places.

6. Quality of water was closely watched to avoid any pollution or epidemic diseases. A quarantine station and the water supply department often examined and analyzed the water in the wells, in the water works, and in the pipes. Slightly low quality water was simply chlorinated. Polluting sources caused by the earthquake such as human and animal dead bodies, feces, and industrial waste were cleared away.

7. Temporary second stage pumps were set up on the roofs (covers) of clean water reservoirs in the water works whose second stage pumping houses were damaged.

8. Repair of the water pipe networks:

When the supply capacity was not large the water was delivered to main outlet pipes and to main distribution pipes so that there would be controlled pressure in the pipes. As the supply capacity increased water was delivered to a larger area under higher pressure so that leaks could be found and repaired. The problems were solved one section after another and the delivery area got larger and larger. After two months of repairs the delivery area through the pipe network, was up to 70% as before the earthquake. Since most buildings had collapsed, inhabitants and users had to get water from outdoor water hydrants for quite a long time.

9. Freeze-resisting work on the water supply facilities had to be done before winter came. The simple, promptly built and freeze-proof buildings took the place of the collapsed pump houses. Special attention was paid to the freeze resisting-work on outdoor taps, fire hydrants and other facilities. Meanwhile, the sewers near these facilities were dredged to prevent pooled water from freezing so as to ensure normal water supply and traffic.

10. Methods for repairing pipes and tubes:

Cast iron pipes: The method used to repair pipes which were slightly pulled out at a joint was to pound in aluminum bars. Water could then go through the pipes immediately after the repair. (This method was also suitable for repairing pipes where flow of water could not be stopped). Any broken pipes or joints were cut off then short pipes took the place of the broken ones and quick setting cement was used as filling. Three or four hours after the repair water could be let through. Broken pipes were cut with saws or axes or sometimes by a welding torch. Another method for repairing cast iron pipes was to wrap the cracked pipe using clamps with quick setting cement.

Reinforced concrete pipes: The broken and cracked pipes and fittings were wrapped and covered with quick setting concrete. The edge of the pipe where the rubber seal was out of place was refilled with self-stressing cement mortar.

From the experience of recovering the water supply after the earthquake in Tangshan we have come to know the real meaning of "water supply is a lifeline of the city". In order to ensure that the water supply system could be restored after an earthquake some suggestions and proposals on the plan, design and administration of the water supply system are as follows:

1. An anti-seismic defense in the water system should be considered in cities in seismic areas. The seismic standards of important buildings (such as outlets, first and second stage pumping houses) of the water supply system should be a little higher than the basic earthquake design intensity in the area. Other buildings should be designed according to the basic code intensity.

2. Water sources and water works should be separated from each other in the water supply plan. An underground water source has obvious advantages. Standby pressure wells in different parts of a city play an important role in restoration (because of fewer links in the flow course and faster recovery for water supply). The city should have as many such wells as possible. The municipal authorities in charge of the water supply should have the spare wells of enterprises connected with the city pipe network in case of emergency.

3. There should be two independent power sources to supply power to the water works to avoid complete power failure. The water supply system should be a priority unit to be provided with power when the power supply is resumed. The water works should have a certain quantity of equipment in storage such as diesel generator sets, diesel pump groups, etc.

4. We suggest that the volume of clean water reservoirs should be larger than or normal usage so that more water can be provided for inhabitants, fire control, medical work, and emergency work if the water supply system has been destroyed.

5. All structures and pipes of the water supply system should be laid on a good foundation keeping clear of subsiding areas, backfill, mud and places where landslides easily occur. If it is impossible to avoid such places special design of the foundation must be done and pipes must be reinforced.

6. The reservoir should be a semi-buried reinforced concrete structure. The reservoirs of cast-in-place concrete have excellent anti-seismic qualities though the cost is larger. Judging from the performance of the pre-stressed, pre-cast 4,000 m^3 reservoir during the earthquake, cast-in-place bottom plates and pre-stressed assembled wall plates can meet the requirement of no leaks caused by a strong earthquake. It will have better seismic qualities if the connections are reinforced at the joints between prefabricated components: columns and beams, beams and roof plates, roof plates and walls.

7. The layout of the delivery pipe network should be strictly in accordance with the regulation that "important pipes should be doubled and delivery pipes should be circled." Valves, outlets and drainage pipes should be rationally arranged in the pipe network. These valves must be well maintained to ensure easy turning. Maintenance personnel should be knowledgeable about the layout of the pipe network and valves, and keep the essential drawings and data for emergency repairs.

8. The main underground outlet pipes should be away from any buildings for fear of more difficulties in repairs after buildings collapse over the pipes.

9. The main outlet pipes should avoid crossing any large sewers or civil air defense tunnels. When necessary, the pipes must be reinforced for fear that the pipes will break and water will flow into the tunnels.

10. More water hydrants and fire hydrants should be located in public squares, and on roadsides near the source wells so as to supply water to inhabitants in case of an emergency.

11. Wall jacket pipes and soft fillings should be used when a pipe goes through any structure. We suggest studying and improving the joint between a pipe and component, and the joint at a water-meter so as to minimize stress and reduce the possibility of damage.

12. Material selection:

Though steel pipes are expensive and not corrosion resistant they are anti-seismic. Such pipes should be applied at the sections across a river or soft soil foundations. Cast iron pipes, pre-stressed or self-stressed reinforced concrete pipes with rubber or elastic joints also have anti-seismic qualities. It is easy to repair cast iron pipes so cast iron pipes with rubber gasket joints should be developed. From our experience we suggest that the following problems should be solved for concrete pipes which are widely used in China: 1) The products should have more varieties and specifications including pressure grades, different diameters, etc. The products, including rubber joint rings (gasket) should be designed to improve their adaptability. 2) Pipe installations and parts should be specially designed. 3) Sealing quality and elastic deformation quality of the rubber joint gasket need improving. 4) Effective, simple and convenient repair materials and parts must be developed for quick repairs.

13. Pipe maintenance must be mechanized. After an earthquake prompt repair of pipes is an urgent, arduous task with strenuous labor. So, it is particularly important to improve the mechanization of pipe construction (especially earthwork, hoisting, drainage, pipe-cutting etc.). Different units should be equipped with different special machines and tools according to their different needs.

14. Rational quantities of mechanical and electrical equipment should be in storage such as pumps, transformers, switchboards, starters, valves, etc., as well as quick setting cement, tinned aluminum cast iron pipes and pipe parts and other materials. They should be stored in anti-seismic warehouses so they can be easily taken out in case of an emergency.

REPAIR OF ELECTRIC SYSTEM POWER

Zhang Jinglong*

Before the earthquake the Beijing-Tianjin-Tangshan power system consisted of power plants from seven regions (Beijing, Tianjin, Tangshan, Zhangjiakou, Baoding, Chengde, and Qinhuangdao) in the same network (see Fig. 1). The installed capacity of the entire system was 3.14 million kW and it generated power of 2 million kW.

Tangshan City had two power plants, the Tangshan Power Plant (with installed capacity of 305,000 kW) and the Douhe Power Plant (750,000 kW). The load in Tangshan Prefecture was 410,000 kW.

I. Damage to Power Construction

I) Power net system

After the earthquake all the plants in the Tangshan area were inoperative. All the switches on the transmission lines to Tangshan tripped off so the two systems in Chengde and Qinhuangdao were separated. They had to operate individually. In Tianjin a few generator sets were suspended from generating power but most of them were still in operation in the combined network with Beijing, Baoding and Zhangjiakou. The generating capacity of this system was 0.99 million kW. The frequency instantly rose to 51.28 HZ. The earthquake occurred in the early morning during a time of low power load. The load cut off by the earthquake was approximately equal to the capacity of the idle generator sets so there was no instability in the power system.

The Central Dispatching Office of the Beijing-Tianjin-Tangshan system lost touch by telecommunication with each plant or substation in the east part (Tangshan, Qinhuangdao and Chengde) and with the wave carrier station because of the power failure. The power failure caused great difficulty in the inhabitants' lives and in the earthquake relief work.

II) Power plants

The earthquake caused 26 steam-turbine generator sets to trip off, the capacity of these was 1.06 million kW. The Tangshan Power Plant and the Douhe Power Plant were seriously damaged. The details follow.

The Tangshan Power Plant was located in a town at the foot of Dacheng Hill. The plant had ten generator sets with a capacity of 305,000 kW. When the earthquake broke out all the generator and boiler switches tripped off automatically except for the No. 4 generator and No. 3 boiler which were being overhauled at the time. The emergency exits of the boilers started exhausting steam into the air and the boilers stopped working. All the operating generator sets

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were damaged to different extents. The entire plant (including the old plant and the new plant) stopped generating power.

Damage to the workshop of the old plant was slight. The No. 0-No. 3 generator sets and the No. 2 boiler were slightly damaged. The walls of the workshop were cracked in some places and slanted outwards a little. The distance between the two rails of the workshop crane was wider by 4-14 mm. The elevation angle of the rotors was slanted in one direction. The main bushing were worn to different extents. Some small diameter pipes were distorted at the elbows. The glass tube testing elements and prime elements of the pyrological instruments were destroyed.

The bearing seat of the steel roof truss of the steam turbine house at the new plant was displaced and the roof was out of shape. A portion of the reinforced concrete roof fell down and broke the machines. The No. 4-No. 9 generators and the No. 3-No. 9 boilers were seriously damaged. A portion of the steel roof truss over the boiler also fell and broke the boiler.

The following is damage that occurred to the main accessory equipment:

The bases of the 3 natural ventilation-cooling towers were cracked and leaking. The concrete bases of the 48 machine-ventilation-cooling towers were cracked; a gap in the No. 4 tower was as wide as 100 mm. The circulation water tube from the machine-ventilation tower to the steam turbine house, which was 200 m long, had 19 cracks 50 mm to 60 mm in width. The reactors, filters and softeners in the chemical treatment workshop were displaced. The joint pipes were terribly distorted. The pump house of the chemical workshop collapsed and all the pumps were broken. There were two coal conveying bridges, A and B. Bridge A was good in general but the main piers of Bridge B were all cracked. Portions of the ash tube were displaced and broken. Of the three reinforced concrete chimneys (one was 100 m tall, the other two were each 80 m tall) one (80 m) was cracked at a height of 35 m and the crack was 50-60 mm wide.

The Douhe Power Plant was under construction at the time, the capacity of which was 0.75 million kW. When the earthquake broke out the No. 1 set of the first phase had already been completed (125,000 kW) and was in normal operation and the No. 2 set had been installed. The workshop building of the second phase was under construction. Both roofs of the houses for the No. 1 and No. 2 sets collapsed during the earthquake and damaged the equipment, 35 m of the top of the 180 m reinforced concrete chimney fell down and broke the coal conveying bridge. Other accessory equipment was also seriously damaged because of the collapsed workshops.

III) Equipment for transmission, transformers and distribution

1. Transmission lines

In the Tangshan area there were 82 lines including 35 kV and 110 kV lines which were in operation and 220 kV lines which had been completed but not put into operation yet, with a total length of 1,592 Km and 8,004 pylon bases. In the soft soil, or bog section, 102 bases sank, 373 bases were slanted and 8 pylons fell to the ground. Also, the porcelain insulators used in the 35 kV lines were mostly cracked, some were even broken.

2. Transformer substations

There were 37 transformer substations in the Tangshan area: one 220 kV, nine 110 kV and twenty-seven 35 kV. The earthquake caused power failure to 33 substations including the 220 kV, 8 of the 110 kV and 24 of the 35 kV. Damage to equipment at the substations was mostly caused by collapsed buildings, e.g. control rooms collapsed and damaged 98 control boards, instrument dials and relay protection boards amounting to 21.4%; switch rooms collapsed and damaged 83 switch cubicles of 6-10 kV covering 26.1%; and 9 sets of DC equipment were damaged (23%). The outdoor porcelain high voltage equipment whose center of gravity was high was also terribly damaged. For example, one 220 kV circuit breaker and nine 110 kV circuit breakers, which were all domestic high voltage circuit breakers with small amounts of oil, were broken at the bottom (18.8%). Ten of the domestic 220 kV high voltage arrestors (80%) broke at the bottom and so did twelve 110 kV arrestors (30%). Most of the 35 kV circuit breakers had large amounts of oil, 13 of them near the epicenter were slanted and the stands were bent and distorted (8.9%). Fifteen main transformers at the substations were damaged (21%). Damage to the main transformers was mostly due to the transformers being displaced (some toppled down) and the sleeve lead wires were broken or cracked at the bottom.

3. Damage to the distribution lines

The distribution lines were not seriously damaged and the damage rate was small, 85 poles fell or broke due to collapsed buildings or soft foundation (0.7%). Four distributing transformers fell off their stands and 81 were displaced (7.5%).

II. Repair of the Power Construction

On the day of the earthquake the authorities and experts from the Ministry of Water and Power and the Beijing Power Administration Bureau established a “Command Office for Earthquake Relief and Power Construction Repair”. The repair work was to be carried out in four stages; 500 people in the first stage, 500 in the second stage, 700 people in the third stage and 900 in the fourth stage.

I) The procedures for repair

The urgent task in the first stage was to determine how to transmit power from other regions to Tangshan. On the day of the earthquake two diesel generator vehicles were dispatched from Beijing to Tangshan, one was 75 kW and the other was 48 kW, which supplied power to the Tangshan command offices only 16 hours after the earthquake. Meanwhile, the transmission line from the Yutian to the Jia'anzi transformer substations and the No. 2 transformer (the main one) at the Jia'anzi Substation were undergoing emergency repairs. The city of Tangshan received power from Beijing at 18:00 on July 29, and in the early morning of July 30 the wave carrier communication from Beijing to Tangshan was restored. At 20:00 on July 30 the lighting circuit was supplied with power. In the early morning of July 31 electrical power began being supplied to the water works. The power source to the Relief Command Office was supplied by diesel generators. During the two days of July 31 and August 1, the power supply to eight major mines was restored.

In the second stage Tangshan was to receive its power supply through four 110 kV lines from four directions, i. e. from Beijing, Tianjin, Chengde and Qinhuangdao, instead of one line from Beijing. At the same time all eight 110 kV transformer substations resumed supplying power. Thirteen of the 24 damaged 35 kV substations resumed power supply. On August 7 the street lamps on more than 20 main streets were lit. On August 10 power was supplied to the suburbs and to the 10 counties of Tangshan, which was necessary for disaster relief, restoration of agricultural production and grain processing.

The No. 2 and No. 1 generator sets were put into the network on August 11 and August 14 respectively after emergency repairs.

On August 5 the Tangshan Power Supply Bureau resumed work and began receiving users. Up to August 14 the power supply to more than 100 enterprises was recovered and the load in the Tangshan area rose back to 70,000 kW.

The third stage was to increase transmission capacity to the disaster area. From August 15 to August 21 the Dou-Han Line, the Dou-Lu Line (both were 220 kV) and the main 120,000 kVA transformer at the Lujiatuo substation were repaired after round-the-clock work so that the 220 kV power source could be transmitted to Tangshan. The supply capacity was up to 0.1 million kW. Meanwhile, the 33 damaged transformer substations were finished being repaired and with temporary measures being taken they received power on August 19. On August 27 the load in the Tangshan area was up to 0.138 million kW including 40,000 kW to the coal mines, and 183 enterprises resumed their power supply. During this stage the buildings of the Tangshan Power Plant were repaired and this created good conditions for the emergency.

In the fourth stage the emphasis was put on the power plant instead of transmission and substations. The No. 0 and No. 3-6 generator sets of the Tangshan Power Plant were repaired, connected with the network and began generating power which made the capacity of the plant rise to 150,000 kW. The 60,000 KF phase modulator at the Lujiatuo Substation was repaired; every substation was equipped with a 100,000 KF electrical capacity which played an important role in keeping a good quality of voltage after the earthquake. Some earthquake-proof measures were taken on the equipment to improve their reliability during aftershocks.

By the end of September the supply capacity in the Tangshan area added up to 0.3 million kW (150,000 kW from the Tangshan Plant, 100,000 kW from the 220 kV line and 50,000 kW from the 110 kV line) meeting the needs of the disaster relief and the recovery of production.

The No. 7-9 sets of the Tangshan Power Plant were severely damaged and after repairs they were joined with the network and began operating on October 8, November 22 and November 25, respectively. Then, all ten generator sets of the Tangshan Power Plant were finished being repaired.

The facilities of the Douhe Power Plant were very seriously damaged. After special repairs the No. 1, No. 2, No. 3, and No. 4 generator sets were joined with the network and began operating power respectively on November 6, 1977, November 19, 1977, February 7, 1978 and August 10, 1978.

II) Technical measures in the repair

1. Generating equipment

The undamaged generating sets (No. 0-5 generators and No. 1, No. 2, No. 5-9 boilers) were overhauled to the standards for their turbines, boilers and electric, pyrological and chemical equipment except that the steam turbines were not opened and the rotors of the generators were not taken out. The water delivery pumps, circulating water pumps, induced draught fan, and forced draught blowers were checked section by section and repaired, and then put into operation. At the same time public facilities were repaired such as, equipment for power sources, industrial water systems, chemical treatment, deep-well systems, water circulating and coal conveying and ash-removing systems.

The damaged items (No. 6-9 generators and No. 3, No. 4 boilers) and the cylinders of four steam turbines of the Tangshan Power Plant were all opened, checked and repaired by replacing broken vanes; centering and dynamic balancing; taking out rotors and overhauling the generators; adjusting the elevation angle of the sets; replacing or thoroughly repairing the broken valve wheels, electric transmissions, tubes and all kinds of instruments.

As for the worst damaged set, No. 9, when the cylinder was opened it was found that a lot of double ring rivets at steps 7, 12, and 18 fell off or were cracked. A vane at step 20 fell off and 102 vanes were cracked at the bottom. The rotor of the steam turbine was sent to Beijing for repair. Other generator sets were checked and repaired in the plant.

2. Transmission, substation, distribution and equipment

The first problem in the repair of the transformer equipment was relay protection. The houses of the substations collapsed and damaged the relay protection boards. The undamaged ones could not be used because the lead wires were buried. Without relay protection the electrical apparatus could not be put into operation. In order to provide power as soon as possible some technical measures were taken in two steps. The first step was to hang the over-current relay (wrapped in plastic cloth) on the frame stand near the circuit breaker box so that power could be supplied during the first and second stages of repair. This measure was easy, convenient and more reliable than if the fuse wire took the place of the relay. Though it was dust proof and waterproof it could not be used for a long period of time. In the second step a special relay protection box was designed and fixed near the circuit breaker which was called an “anti-earthquake protection box”. In this protection box there was equipment for over-current, quick-break and auto re-close circuit breakers for meeting the power supply demand.

The situation was the same with the damaged control boards and instrument dials. Simply built wooden houses served as temporary control rooms at 110-220 kV transformer substations and at important 35 kV substations with main instruments and control boards in them. The circuit breakers of 35 kV or less than 35 kV were repaired and operated on on the spot.

All the damaged DC apparatus, porcelain sleeves of main transformers, 220 kV and 110 kV circuit breakers and arrestors were replaced. All the high-voltage apparatus were tested for insulation quality before putting them into operation and only the qualified ones were allowed to be switched on. Oil filled equipment such as transformers and circuit breakers were refilled with

oil and after an insulation test they were put into operation. Insulation oil which had been contaminated with moisture was replaced.

Some of the 10 kV switch cubicles were broken due to collapsed buildings and the unbroken ones could not be used. During the first and second stages of emergency repair fuses were fixed on the 10 kV switches to temporarily take the place of switch cubicles so that power could be transmitted as soon as possible. In the later period of emergency repair (the third and fourth stages) in the substations where there were a lot of 10 kV lines, the switch rooms were built out of asbestos boards and angle irons with 10 kV switch cubicles installed in them for transforming power.

Earthquake-proof measures were taken on the repaired equipment. For example, the chassis of the transformer and the base were welded together and four guy wires were used to stabilize the transformer. The lead wire of the porcelain sleeve of the transformer was changed to a flexible wire. Insulated guy rods were fixed to the porcelain equipment whose center of gravity was high.

All the transforming and distributing lines were thoroughly checked and repaired (repair workers climbed up the poles for repair). The damaged parts were replaced, the slanted poles were straightened and the defects that may have hindered the power supply were eliminated.

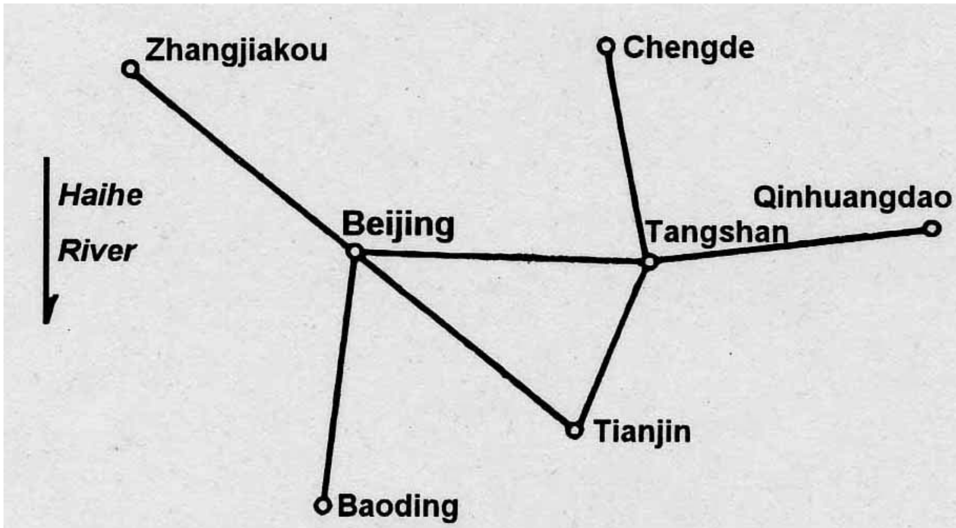

Figure 1. A sketch of the network of the Beijing-Tianjin-Tangshan power system before the earthquake.

REPAIR OF THE POSTAL AND TELECOMMUNICATION SYSTEMS IN TANGSHAN

Liu Yinghe*

Located at the border of North China and Northeast China, Tangshan is the center joining Beijing to the three provinces of Northeast China. Not only is it an important traffic line but also a hub of telecommunication with the country's main long distance lines and underground cables running through it.

I. Conditions of Postal and Telecommunication Systems Before the Earthquake and the General Situation of Earthquake Damage in Tangshan

Before the earthquake there was a local (municipal) telephone building (automatic exchange telephone building), a long distance central building, a wireless station and a repeating station in the city which formed a "nerve center". This connected 15 post offices, 119 branch offices, 3,348 agencies in 13 counties (districts) as well as more than 2,000 users of telephones and telegraphy in town.

The local telephone building of the Municipal Bureau was an automatic exchange building with apparatus for 2,400 telephones. It was a three-story brick and concrete building. The building collapsed in the earthquake and all the apparatus were damaged.

The long distance call center on Huayan Road, which was a three-story inner frame structure, collapsed during the earthquake. The equipment on the second and third floors was damaged which broke off all phone and telegraph telecommunication to the big cities such as Beijing, Tianjin, Shijiazhuang and Qinhuangdao and to more than 100 circuits in the 13 counties of Tangshan Prefecture. The phone communication from Beijing to the three provinces in Northeast China was also suspended.

The main exchange house of the wireless transmission station in the west suburb was a single-story structure constructed of bricks and concrete. The walls were cracked and the frame of the main device was displaced.

The single-story main exchange house of the repeater station of the long distance cable, located more than 10 kilometers northwest of Tangshan, was cracked during the earthquake.

Around the city most of the open-wire poles fell, sank, toppled over, or displaced which caused broken lines and bad connections. Collapsed buildings damaged some local lines in the urban area; some were broken by ground fissures. The communication supports along bridges were out of shape which caused broken lines and mixed wires when the bridges collapsed.

The collapsed postal and communication buildings in the city were 4,0591 m^2, covering 96% of the total building area. The damaged equipment covered 83.9% of the main equipment.

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Among them, 2,400 automatic exchanges were completely damaged, and 291 of the 347 sets of long distance and local call equipment were broken; 55 sets of postal transportation vehicles and motorcycles were damaged covering 81% of the total.

II. Repairs for Recovery after the Earthquake

After the earthquake there was only one special line left keeping in touch with Beijing and Tianjin at a manrepeating station in the outskirts of Tangshan. It was through this line that at 5:15 on the morning of July 28 someone got in touch with the Beijing Long Distance Telecommunication Bureau and reported in detail the disaster to the Ministry of Posts and Telecommunications. No sooner had the report been received than the Ministry founded an earthquake relief office which was to be in charge of relief work for the telecommunication system. Emergency repair groups were sent to Tangshan immediately and a plan was made to get lines through and to repair main lines and important facilities first.

At the same time the Provincial Bureau of Posts and Telecommunications took some emergency measures:

1) All vehicles in the units under the Provincial Bureau were held for simultaneous dispatch.

2) The Provincial Bureau established an earthquake relief command office and emergency repair groups were immediately sent to Tangshan.

3) The Provincial Line Service Station, the Telecommunication Construction Brigade, the post offices of eight prefectures (except Longfang) and the departments concerned were ordered to organize relief groups to help Tangshan with tools, materials and goods.

4) Urgent telecommunication materials and goods in warehouses were allocated to Tangshan.

5) A group of radio men were flown to Tangshan carrying transceivers together with the first relief group of the provincial government.

6) The communication vehicles prepared for war were put into use.

After the earthquake more than 1,200 people and 123 automobiles with large quantities of telecommunication equipment and goods from 9 provinces flowed into the disaster area day and night.

The procedures and methods for telecommunication emergency repair were as follows:

1) First of all, a communication network was established with an on-the-spot command office as its core forming a local phone system and a long distance call system with a command station in the outskirts.

2) Since neither wired nor wireless communication could be used, the underground cable in the outskirts served as a special line contacting the command office with the CPC Committee.

3) Transceivers were used to get in touch with the provincial capital of Shijiazhuang as soon as possible.

4) On the basis of conditions, the backup power was used and new lines were set up.

5) The provincial line was tortuously connected from Shijiazhuang to Tangshan through Chengde-Qinglong-Qianxi by unified control.

6) The 60-channel wave carrier circuit was connected between Tangshan and Beijing and the new telegraph from Tangshan to Beijing and from Tangshan to Shijiazhuang was opened up by making use of the telecommunication vehicles prepared for war and the main underground cable.

7) The long distance open wires and phone lines in the countryside were checked and repaired according to a unified plan. Work was assigned to each individual group.

8) Plastic covered cables were used and manual exchangers were installed to put calls through to important users forming an on-the-spot command center in the city.

9) New automobile mail lines and air mail lines were opened up. The problems of interruption were solved in many ways.

Because of the emergency measures mentioned above, the circuit between Tangshan and the CPC Central Committee went through at approximatley 10:00 on the morning of the earthquake. Tangshan was put through to the three counties of Funing, Qian'an and Fengnan by a relay trunk cable. The main telecommunications got through by emergency repairs during the three days of July 28 to 30 (see Table 1).

After the main lines got through repair groups from 9 provinces began recovery work with the workers of Tangshan. Up until the end of August, 64 various sets of equipment were installed. The newly installed carrier equipment approached the level before the earthquake. The number of long distance circuits was up to 116, 13 more than the number before the earthquake. Telephone service from Tangshan to every county was restored. One hundred local circuits and eleven magnet exchangers were installed serving 230 users. For radio communication the circuits from Tangshan to Shijiazhuang and Tangshan to the reservoir were restored, besides, 14 new circuits from Tangshan to every county were opened up. The telex circuits between Tangshan and Beijing, and Tangshan and Shijiazhuang were also opened up by means of wired telegraph.

On September 1, the telegram business resumed and nearly 400 circuits from every county and town to communes was restored. The postal transportation from Tangshan to the counties was also restored. The municipal postal business was as good as before the earthquake except for the parcel business and telegraph remittance business.

III. Some Proposals

In order to reduce disaster loss of the postal system and keep its normal function during an earthquake some suggestions and proposals were made as follows:

1) Because postal and telecommunications are one of the engineering lifelines in the city, the anti-seismic design standard of all buildings should be improved. For example, at the telecommunication exchange building: the "three rooms" (exchange room, phone room and

telegram room); the long distance cable and open wire repeating station; the microwave station; the transceiver station; and the municipal call exchange room, etc.

2) The bases of all telecommunication equipment should be reinforced and anchored in all directions so as to improve its anti-seismic resistance.

3) Long distance wire poles and local open wire poles, terminal poles, leap poles, fly-over poles and angle poles should be reinforced by guy wires, struts, and by putting up neighboring poles, etc.

4) It is best to use expand-proof wire coated cables in the mineshafts and in subsiding areas. The submerged cable should be reinforced especially the sections that cross rivers.

5) Basements should be included in the plans for standby rooms. Precautions should be taken against any blockage of underground exits.

6) A radiation-like telecommunication network is needed. A multi-office system should be adopted in town. There should be many different delivery methods.

7) Telecommunication circuits need many exits. Having only one line for one destination should be avoided.

8) There should be normal use equipment and spare or standby equipment both for wired communication and wireless communication. Technical personnel should be experts at one thing and good at many. Important technical drawings and data should be filed in many sets.

9) Postal and telecommunication offices of different levels should have, in advance, a dispatch plan for the emergency repair and recovery of damaged telecommunication circuits. A certain quantity of telecommunication materials and goods should be kept in storage.

10) Postal and telecommunication staff and workers should be further educated in anti-seismic knowledge and knowledge about disaster relief, repair and recovery.

Table 1. Time of establishing postal and telecommunication after the Tangshan earthquake.

Item	Time of Recovery			(Telecommunication Means) Units at Both Ends	Unit of Emergency Repair for Recovery
	Month	Date	Hour/Min.		
Telecommunications □	7	28	5:15	(underground cable) Tangshan Suburb Station-Beijing Long Distance Bureau	Suburb Station of the Tangshan Bureau
	7	28	13:20	(transceiver) Tangshan Command Office-Shijiazhuang	Transmission Station of the Provincial Bureau
	7	29	7:20	(12-channel carrier) Tangshan Suburb Station-Tianjin, Beijing, Shijiazhuang, Shenyang	Tianjin Long Distance Telecommunication Bureau
	7	28	P.M.	(local telecommunication) Tangshan Command Office, local junction	Liaoning Provincial Postal and Telecommunication Bureau
	7	29		(roundabout route) Tangshan-Shijiazhuang	Hebei Provincial Postal and Telecommunication Bureau
	7	29	P.M.	(60-channel carrier) Tangshan-Beijing	Beijing Long Distance Telecommunication Bureau
	7	30		(telex) Tangshan-Beijing, Shijiazhuang	Beijing Long Distance Telecommunication Bureau
Postal□	7	29		(air mail) Tangshan-Beijing	Post Offices of Beijing and Tangshan
	7	30		(airmail) Tangshan-Shijiazhuang	Post Offices of Shijiazhuang and Tangshan
	7	30		(new motor route) Tangshan-Beijing	Post Office of Beijing
	7	31		(new motor route) Tangshan-Tianjin	Post Office of Tianjin

DEALING WITH EMERGENCIES AND REPAIRS FOR THE PRODUCTION TECHNOLOGY OF THE TANGSHAN STEEL AND IRON CORPORATION

Wang Daming*

I. Outline of Earthquake Damage

The Tangshan Steel and Iron Corporation was located in the area of intensity X of the earthquake. There were 320,000 m^2 of industrial buildings, 12% of them collapsed or were seriously damaged. The partially damaged buildings accounted for 70% and only 18% remained basically intact. There were about 160,000 m^2 civil buildings in the area and 90% of them were damaged.

In the workshop area there were 41 industrial chimneys and 34 of them cracked, dislocated or toppled down; 3 sets of brick-laid water towers with a capacity of 125 tons all collapsed; reinforced concrete columns at the bottom of 4 sets of water-cooling towers collapsed; among the 15 heavy oil pots (located near 4 key workshops) there were 3 places that were seriously leaking oil; and 20 of the furnace-kilns were damaged to different degrees.

At the ironworks 4 sets of 100 m^3 blast furnaces and relevant hot blast stoves and pneumatic dust-removal systems basically remained in good condition. Due to the cut-off of the water and electricity supply after the earthquake all the molten iron solidified in the furnace. Because the water supply was cut-off for such a long time the furnaces were seriously deformed and they could not operate continuously. Among the 4 units of frame-type stock warehouses made of concrete, one toppled down and the support props of the other 3 either cracked or were badly rifted. The shaft kiln of spherical aggregate sintering was abandoned because of the complete collapse of its reinforced concrete frame support structure.

At the steel mill the cupola furnace, converter, and the ore-heating stove of the iron alloy plant became frozen due to the cut-off of water and power. The high stock warehouse of the converter and cupola completely collapsed. Due to the collapse of the workshop buildings the equipment in the other auxiliary facilities failed.

At the steel rolling mill the vein piping of the heating furnace burned and broke, but the key rolling structure basically remained in good shape. In the main power room the power supply facilities and key generators suffered partial damage due to the collapse of neighboring workshop buildings.

In the public system the air supply was decentralized through high supported pipes. With the exception that a number of air pipes were displaced or fell off, all the others survived. The water used for production mainly came from the Douhe River but a portion of it came from tap water or deep wells. There were 2 river water pump stations, 9 deep well pump stations, 10

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pressurization and circulating pump stations, 3 water towers and 12 km of water supply piping. Besides, 3 water towers toppled down and a number of connecting points of the underground piping were found loose, cracked or broken off. At the 2 transformer substations the transformers were all displaced, the secondary bus was broken by pulling, casing pipes were smashed to pieces, the brick wall of the substation room toppled down, the room roof fell off, and most of the equipment in the room was broken. The electrical transfer towers were deformed. The 3 air intake chimneys of the oxygen supply station all collapsed, the 600 m^3 oxygen making machine and its relevant equipment was seriously damaged because the building collapsed; 129 sets of railway switches were displaced. After the M7.8 earthquake the operation of the plant stopped completely.

II. Dealing with Emergencies after the Earthquake to Prevent a Secondary Disaster

1. Oxygen

The 2 steel works in the corporation were equipped with whole top-blown oxygen and whole side-blown oxygen systems. The oxygen came from 5 sets of oxygen making machines (producing 13,600 m^3 of oxygen per hour) and flowed into 3 spherical tanks then through overhead oxygen pipes which was sent to the steel works. When the earthquake took place the electricity was suddenly cut off and the oxygen compressor stopped working. An explosion could have occurred at any time while the liquid oxygen evaporated in its tank. To prevent this from occurring a number of experienced workers drained the liquid oxygen according to regulations and in the meantime emptied the oxygen gas. The goal was to prevent an explosion in case metal things hit each other producing a spark during an aftershock.

2. Power supply

The power supply to the corporation came from the south substation (its capacity was 18,000 kva) by 16 circuits and the north substation (65,000 kva) by 25 circuits with all the overhead cables supported by high voltage towers or poles. During the earthquake all the transformers were displaced, the porcelain insulators cracked and steel towers became twisted. Therefore, the personnel concerned were organized to carefully check on every electric cable, porcelain insulator, cable tower or wire pole one by one in order to prevent casualties or a fire because of partial electric conduction when the electricity was again turned on. As for the substation buildings, all the dangerous conditions were removed in time to avoid disasters caused by an aftershock. For the units which received electricity, their electrical intakes were also carefully examined in order to prevent a secondary disaster from occurring when the electricity was turned on.

3. Water supply

Due to the collapse of buildings during the earthquake the equipment concerned was damaged. Since aftershocks were successively taking place they quickly dealt with eliminating dangerous conditions at the pump station. The repair work was hurried in order to prevent equipment damage if the buildings toppled down. Meanwhile, the water pipe and valve problems were handled quickly in case water flowed over motors or other devices. Since

recovery of the running water system in the urban district took a considerably long time, the repair of the deep well pump stations was given high priority.

4. Oil supply

There were 15 different sized oil tanks in the corporation located in 4 places. During the earthquake, due to the breaking of pipe connections at the tank outlet valves, a lot of heavy oil flowed into the drainage ditch network and went into the Douhe River. Some of the oil flowed into workshops, some even blocked the entrance of the 1st pump station and some oil fully filled the escape canal of the drainage network creating a secondary disaster bringing about great difficulty in production recovery. Hence, an examination of the oil tank to sluice gate, valves, and pipeline were carefully done one by one to find damage and repair them in time. In addition, the overflowing heavy oil was cleaned up.

III. Emergency Repairs

1. Smelting system (steel smelting, iron smelting, iron alloy, casting and other plants)

1) Chimneys

The dust exhaust chimney of the steelworks and the hot-air-blast chimney of the ironworks all toppled down 1/3-1/2 from the top and their lower parts showed dislocation. They were completely removed and steel chimneys were erected as there was no repair value; these could be built quickly and were better in anti-seismic performance but their service life was shorter.

2) Furnaces

After the earthquake the furnace's foundation bolts became loose and its body tilted. When repaired, the body of the furnace was returned to its upright position by jacking; its center alignment was adjusted precisely; then, concrete around the loosened bolts was dug out and the bolts were welded by lap splicing. Finally, the foundation was consolidated with reinforced concrete.

Because the water supply was cut-off for a long time 100 m^3 of blast furnace became solidified; its foundation sank unevenly; the No. 4 blast furnace moved 30 mm and its water-cooling fire bars all burned and broke. The foundation of the furnace body remained unhandled and the furnace chamber was cleaned with explosives and the steel plates in the furnace belly were replaced. After the water-cooling fire bars were renewed and the furnace was lined anew, it was put into production.

The hot-blast stove was split open mostly inside at the brick seam and partly fell off and a portion of the chimney top made of stone masonry fell down and the foundation settled. Only part of it was repaired.

3) Stock warehouse

The material-feeding warehouses equipped for converter and blast furnaces were all built with concrete frames supporting steel bins. During the earthquake the high stock bins of the No. 2 steelworks were fully filled. Because the columns of the frame broke all the bins fell

down. There were 5 bins equipped for the No. 1 blast furnace and they all toppled down. The No. 2 warehouse had 5 bins; the foot and head of their columns cracked and their steel bars became twisted. The No. 3 warehouse had 6 bins; due to the broken column tops the whole body slanted by 160 mm. The No. 4 stock house had 5 bins and all of them sank 40 mm. All of the stock bins that toppled down were rebuilt with steel columns replacing the original ones. The repair plans for the stock houses that were partly damaged were as follows:

a. To support the overhead bin, remove the original concrete columns and replace them with steel columns.

b. To return the toppled down store bins to their original positions first, reinforce the column head, and add cross diagonals.

c. If the column head cracked it could be strengthened by removing the concrete then new steel bars were welded to existing bars and concrete was poured.

d. For slight cracking of columns steel angles were used to wrap around the columns.

4) Sloping feeding bridge

The stock feeding sloping bridge and its feeding entrance of the iron smelting stove in the No. 1 steelworks inclined northeast by 50-60 mm. The big stock-hopper of the No. 3 blast furnace inclined east 60-70 mm. The upper transverse beam of the sloping bridge of the No. 4 blast furnace turned around 60 degrees. When being repaired the furnace body was first returned to its original place. After leveling it and aligning it and making sure it was in the right place the material-feeding entrance was used as the center to align the bridge with the furnace body then the equipment was firmly reinforced.

2. Steel rolling system

1) Heating furnace

All the longitudinal or lateral stove pipes of the heating furnace at the 4 steel rolling workshops were burned and toppled down because there was no water supply, and cooling and uprising pipes which were connected with the furnace pipes were displaced at different amounts. The furnace wall and flues cracked and became loose. There was one furnace top that was smashed when the chimney fell down. After the furnace vein pipes of the broken furnaces were replaced one by one and the furnace walls and flues were slightly repaired so they could be operated. But before water was supplied a pressure test was conducted and finally the heating furnace could be operated.

2) Main rolling machine

The rolling machine had its own foundation. After the earthquake it was inspected and no problems were found and the drive system was not damaged. The main power room was next to a main production building, the walls of the later toppled down and part of the key motors and the high-voltage power supply system were smashed. The main rolling system was put back into production only after general tests and repairs.

3) Fuel system

All the 4 rolling mills used heavy oil as fuel. There were 13 oil tanks of 300-1,000 tons in capacity for each. After the earthquake their enclosing wall toppled down and 3 tanks with a storage capacity of 1,000 tons each had their outlet broken which released oil. The drainage networks at each mill were blocked which was a secondary disaster. All the fuel pipelines were overhead. There were no abnormal situations except for a few that were displaced and their supports fell down. When the repairs were being done the fuel leaks were found and repaired.

4) Others

Due to the toppling down of pump station houses some of the equipment was smashed and there were a few broken connecting joints of ground pipelines. No other big abnormalities were found. The tracks of the shop traveler twisted and displaced because of the uneven settling of the columns.

3. Auxiliary system

1) Kiln

Nine sets of the lime-roasting kiln laid with bricks all toppled down. Inside the inverted flame kiln and in the top movable kiln of the refractory plant the linings became loose and part of them split; the tunnel kiln remained normal. The body of the dolomite stove had no damage except that its concrete frame columns were cracked at the top. Only general medium repairs were conducted on it and it was put into production.

2) Foundations

The foundations of various milling machines, stoneroller and brick-pressing machines, etc. all had uneven settling; the depth of sinking was less than 40 cm. The main part of the equipment also partly displaced. The outlet and inlet connecting the main equipment with the conveyer belt and pocket hopper machines opened at the welded seams or became twisted. Repairing only the levels and alignment of the equipment was enough.

3) Stock bin

When the earthquake occurred the limestone coke storage bins at the No. 2 steelworks were all fully filled. Due to poor design the columns bent and the bins fell down. Several elevated stock bins in the stock factory were steel structures and had shear bracing members so mainly no damage took place. At the Houtun Stone Mine, though the stock bins were steel structures, there were no shear bracing members so during the earthquake they all slanted and sank unevenly. At the refractory plant the stock bins were steel structures and during the earthquake their brick-laid enclosing wall partly collapsed. When being repaired all the materials in the bins were removed, the container was then hoisted with a jack and when the container was lifted up to its original place it was fixed and reinforced. Finally, the brick wall was removed and a steel structure was built instead as a safeguard.

4. Public system

1) Pneumatic system

With the exception of the safety valve of the compressor being smashed by the collapsed building of the compressor station at the casting plant, there was no damage to the major equipment at all the other air compressor stations. Foundations only sank slightly and pipe-shifting and joint-disconnection situations were found. All were handled on the basis of medium-scale repairs.

2) Water supply system

During the earthquake the major section of the deep well pump house partly collapsed but the pump was unbroken. With no electrical supply the deep well pump was driven by a diesel generator and a truck wheel and belt.

The leak at the water pond was repaired with quick hardening concrete.

3) Power supply

During the earthquake 6 transformers all had displacements, tilted and were off their tracks. The displacements were 50-500 mm and some of the bars were pulled and broken. Some high voltage porcelain insulators cracked, and there were 3 steel transmission towers that became twisted and crooked and one pole fell down. All the usable elements from the two substations were concentrated into one. When the transformer returned to its original place the core of the transformer was taken out to be checked, the oil was changed, and then after a trial run and adjustments it was put back into service.

REPAIRING THE CERAMIC KILNS IN TANGSHAN CITY

Dong Kejun and Wang Shirong*

The kiln is the key equipment in ceramic production. During the earthquake the 123 kilns belonging to the Tangshan Ceramic Industry Corporation suffered damage to different extents.

I. Main Structure of the Kiln

The Tangshan Ceramic Industry Corporation was one of the enterprises producing porcelain articles both for daily use and for industry. There are a large number of kiln categories. There are 16 sintering tunnel kilns; 68 sintering flame inverted kilns; 18 sintering straight flame kilns; 17 baked embossing tunnel kilns; and 4 baked embossing rolling-track kilns. The output of the corporation was 130 million pieces yearly. Most of the kilns were brick concrete structures. The parts of the kilns that were seriously damaged during the earthquake were the kiln-top, kiln wall, kiln foundation, kiln framework, and so on.

1) Kilns for continuous production (tunnel kiln)

The major part of this kiln is the long tunnel; 20-105 m in length with a net width of 0.4-2.2 m and a net height of 0.5-3.1 m. In light of different temperatures and structures they can be divided into the following categories:

1. Kiln wall structure

When the temperature will be under 500°C the inner wall is built using a No. 25 refractory mortar to lay No. 75 or higher brick or refractory brick with a thickness of 230-240 mm. The outside wall is built with No. 50 mortar to lay brick with a thickness of 370-490 mm; the total thickness of the wall is 610-730 mm.

When the temperature will be higher than 500°C an insulating layer with a thickness of 115-230 mm between the inner and outside wall is added. The insulating layer can be light clay insulating brick or just filling with slag; the total thickness of the wall is 720-840 mm.

For temperatures over 1,100°C-1,300°C in the sintering zone the inner refractory wall is increased to 345 mm and the outside wall is increased to 620-860 mm.

2. Kiln roof structure

For most of the roof structures an arch is built using refractory bricks. In the pre-heating zone and cooling zone (temperature under 1,100°C) the refractory bricks are laid with fine refractory mud and the thickness is 230 mm. The arch is covered with light-clay-heat-insulating brick and a layer of slag with a thickness of 200-300 mm. The insulating layer is a 60 mm thick brick surface. In the cooling zone between the upper layer and lower layer of the refractory brick arch there is a ventilating duct. If temperatures are higher than 1,100°C in the sintering

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zone the inner layer of the refractory brick arch is 300-345 mm thick, the insulating layer is 115-230 mm thick with light clay brick and a layer of 200-300 mm of slag or pearlite layer.

3. Foundation

In general, the foundation is located on a rubble layer with a thickness of 200 mm and it is covered with No. 75 brick 200-300 mm thick and jointed with No. 50 mortar. Under the tracks a ground beam is made of reinforced concrete with a thickness of 200 mm to support moving vehicles.

4. Framework

Most of the tunnel kiln roofs are arched structures; all have arch-foot-beams and pull rod and props forming a framework to bear the lateral thrust.

2) Kilns for intermittent production

1. Intermittent kiln with framework

There are 2 types of intermittent kilns. One type is a rectangular kiln and the other is a round kiln. Their foundations and structures are basically the same and their volume is 7-314 m^3.

a. Kiln wall

In general, the outside wall is laid with No. 75 bricks with No. 50 mortar 620-860 mm in thickness; the inner wall is built with refractory bricks and refractory mud 300-345 mm in thickness. A gap of 30-50 mm remains between the inner wall and the outside wall and a certain insulating material can be filled in-between. The total thickness of the kiln wall is 0.9-1.2 m.

b. Kiln roof

The rectangular kiln has a single curved arch and the round kiln has a double curved arch. Both are laid with refractory brick and refractory mud with a thickness of 300-350 mm. The outside layer is made of a leather-mud sealed insulating layer 220 mm thick.

c. Foundation

In general, the foundation is built with No. 50 mortar and brick over a rubber layer.

d. Framework

The framework is made of belt steel and channel steel.

2. Intermittent kiln without framework

This type of structure is rather old. There is heavy load on the roof and the horizontal thrust is smaller. The kiln wall only bears the expanding forces produced by high temperature and vertical load.

a. Kiln wall

The inner wall is built with refractory brick and refractory mud with a thickness of 350-500 mm. For the outside wall brick or stone is laid with No. 50 mortar with a thickness of 500-800 mm. Between the inner wall and outside wall loess is filled in and rammed as an insulating layer 1 m in thickness.

b. Kiln roof

In general, refractory brick and refractory mud are used layer by layer to form a dome. The so-called refractory brick is 350 mm thick and is finally sealed with a straw-mud insulating layer of 200 mm.

II. Earthquake Damage

Most of the Tangshan ceramic industry enterprises were located in an intensity X area. Because of the differences in geological conditions and different types of kiln structures the damage degrees were different as well.

Kilns suffered more serious damage on weak foundations. For example, the No. 1 and No. 9 porcelain plants were located near the Douhe River; their kilns were seriously damaged. The No. 4 porcelain plant was located in the subsided area of the coalmine under which the coal was mined out and its 9 straight-flame kilns all toppled down. The No. 3, 5, and 10 porcelain plants were situated on a hill slope and due to the ground conditions being better they only suffered light damage.

In general, the outside wall of the kiln was laid by No. 75 bricks with No. 50 mortar. Any kiln that was built without framework such as the old style straight flame kiln fell down completely during the earthquake. Those that had framework such as the inverted flame kiln, in spite of the kiln wall being thinner, only had a few topple down completely.

In general, most of the kiln roof structures were built with special shaped refractory bricks and refractory mud to form single curved arches or double curved arches. The structures had a good integrity so they remained intact. The old style straight flame kilns were not built with framework; their roofs fell down during the earthquake.

There were 3 types of ceramic kiln, i.e. rectangular, square and round. The rectangular shaped kiln (such as the tunnel kiln), had slight damage in general. Most of the square kilns with single curved arch roofs toppled down during the shocks due to the weak connection of the wall with the arch. Round kilns with double curved arch roofs had good integrity, especially the ones having framework which had the least damage.

III. Production Recovery

The key problem for production recovery of the ceramic industry, except for the workshop building, was repairing the kilns. Those that suffered slight damage during the earthquake (about 8%) only needed a bit of repair work to recover operation. Those that suffered serious

damage (about 25%) were overhauled so they could be put back into operation. Those that were completely destroyed (about 67%) needed reconstruction.

In 1977 a large-scale reconstruction and repairs on workshop buildings was carried out. By the end of 1980 there were 117 kilns that were put into production making up 95.12% of the total before the earthquake.

During the earthquake, the kilns gradually stopped operation because the power and fuel supply was cut off. The unfinished products in the kiln had to be scrapped. Since the kiln body (brick, stone, steel, concrete) and the products were all non-combustible materials no conflagration took place.

REBUILDING TANGSHAN

Huang Yuhua and Hou Minzhong[1]

After the earthquake the reconstruction of Tangshan City began in 1978. The total building area was 18.21 million m^2 and the task was expected to be completed by the end of 1985.

The capital needed for reconstruction of the enterprises which were attached to provinces, prefectures and the city governments was raised from their profit and tax relief by the State. The reconstruction funds for those under the direct jurisdiction of the Central Government were allocated directly by the State. The total reconstruction investment was to be 24,400 million yuan.

According to the State's requirements for rebuilding Tangshan the pre-construction preparation work was to be completed in about one year. It included 1:1,000 topographic surveys on urban areas covering more than 240 km^2, a survey on engineering geology and hydrogeology of residential quarters and the industrial district, and designing of construction work. All these were mainly given to the units which came from other provinces and cities to help rebuild Tangshan. Each unit worked independently; the unit in charge of a certain project proceeded until finished. The remaining work was undertaken by the Tangshan City Design Institute and other design units of Hebei Province. Concerned industrial ministries which were directly under a department of the Central Government were to be in charge of design projects belonging to these enterprises.

The construction to help rebuild Tangshan was carried out by units from 15 provinces and municipalities and by engineering troops of the PLA.

To improve the coordination of the reconstruction the Frontline Earthquake Relief Headquarters was set up by Hebei Province and a construction headquarters was also established by Tangshan City.

I. Outline of the New Tangshan

The construction principles of the new Tangshan were: "Be advantageous for production, convenient for daily life, protect the environment and bring benefit to the people". In the plan industrial development of coal mining, steel and iron, ceramics, electricity, building materials, etc. was fully considered and the former disorderly and unsystematic layout of the urban area was avoided; and the serious environmental pollution existing before the earthquake was to be eliminated. It was planned to build the new Tangshan as an anti-seismic city in modern style.

The newly rebuilt Tangshan City would be composed of an urban district, an east mining district and Fengrun (new) District. The distance between any 2 will be 25 km (see Fig. 1).[2]

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[1] Construction Headquarters of Tangshan City

[2] It is not known if this plan was actually carried out. However, the city was completely re-planned and rebuilt, including a new street layout. In 1996, the 20th anniversary of the

The entire city will cover an area of about 810 km^2 (including 2 state-owned farms: Hangu and Lutai Farms). Urban construction will occupy 73 km^2 and the city will have a population of 1,338,304 (data from the State census in 1982).

During the rebuilding some of the inhabitants and factories were moved out of the original Lunan District where the population density was too high before the earthquake. The coal reserves were under the district and it was where serious losses occurred during the earthquake.

There will be a new district named Fengrun New District to be established east of Fengrun County Town. A number of large industrial enterprises will move there including: the Huaxin Textile Mill; the Tangshan Printing and Dyeing Mill; the Tangshan Silk Fabrics Mill; the Tangshan Yarn-Dyed Fabrics Mill; the Tangshan Woolen Mill; the Tangshan Light-Industry Machinery Plant; the Tangshan Gear Plant; the Tangshan Rolling Stock Plant; the New District Heat and Power Plant; and the Jidong Cement Plant, and so on. The new district will cover an area of 7 km^2 and the population there will be controlled at 60,000 or so in the near future.

The rebuilt city proper will be mainly located in the original Lubei District and there will be a little extension toward the west and north. In the city proper the original enterprises such as coal, steel and iron, ceramics, electricity, machine, and so on will not be moved. Besides the city agencies there will be 12 various hospitals, 10 theatres and cinemas, 30 middle schools, 59 primary schools, 2 colleges, a number of secondary technical schools, one teachers training college, and 70 kindergartens and nurseries as well as hotels, restaurants, hostels, department stores, etc. The city proper will cover an area of 40 km^2 with a population of 400,000 or so. Four parks will be built to beautify the environment.

To make things convenient for the people and eliminate a pollution source in the urban district a coking and gas making plant with a production capacity of 400,000 m^3 of coal-gas will be built between the city proper and Fengrun New District.

The east mining district, still consisting of the 5 coal mines (Linxi, Tangjiazhuang, Zhaogezhuang, Lujiatuo and Fangezhuang) will build living and production sub-districts by each mine unit to form small towns; each will have a population of 40,000-60,000 people. Each small town will have its own system and at the same time be able to keep in contact with each other. The total area covered by the east mining district will be 26 km^2 with a population of 300,000 people or so.

All the coal mines in the east mining district including Tangshan Mine in the urban district, Majiagou Mine and Jinggezhuang Mine in the suburban district as well as the Kaiping Coal Field will connect with each other to form a mining zone 100 li long.

In the new Tangshan City there will be railways and highways connecting the 3 districts with each other so that the traffic situation will be very convenient.

The newly rebuilt Tangshan will be more beautiful than it was before the earthquake. The newly built factories regardless of their production scales and technological processes will all

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earthquake, Tangshan was a new and prosperous city with a larger population than before the earthquake.

have big developments. The enterprises, which were simple and crude in equipment as well as small in production scale, will have standard production buildings built and the working conditions of the employees will be greatly improved. A good number of big-sized industrial and mining enterprises will all build modernized buildings and, in addition, buy new equipment so that their labor productivity will be increased. The newly built Jidong Cement Plant will have a production capacity of 1.5 million tons yearly, more than twice the output of the whole city before the earthquake. The ceramics industry will also be developed, except that the original Tangshan Construction Ceramic Factory and several other ceramic factories will be rebuilt to their original production scales. A number of new factories will be built such as sanitary ceramic ones, wall and ground brick ones and glazed tile porcelain ones. The electrical power industry's development is even more rapid. Take the Douhe River Power Plant for example, it will now possess an installed capacity of 1.07 million kW (not including the heat and power plant in the new district, and the special power plant attached to the Qixin Cement Plant and Kailuan Coal Mine) and after the second phase project is completed its total installed capacity will be 1.47 million kW. It will then be the largest power plant in North China and it will be the key plant in the Beijing, Tianjin and Tangshan power network.

The Tangshan Steel and Iron Corporation is one of the middle-sized integrated complex enterprises and will be rebuilt. The Kailuan Coal Mine is one of six famous large coal mining enterprises in China and it will be enlarged and renovated during reconstruction.

The scale of rebuilding residential quarters will improve the quality of life of the citizens. In Tangshan City before the earthquake the streets were narrow, crowded and a mess. Poor quality old small flat roof houses made up 80% of the total buildings in the city. They provided only 3.6 m^2 of living space per capita. The residential construction in the new Tangshan will make a great difference compared with that before the earthquake. Except for the new one-story houses that will be located on soft soils, over 90% of the new dwellings will be 4-5 story apartment buildings and the living space per capita will be more than twice the 3.6 m^2 before the earthquake, and new Tangshan will become the first city whose living space per capita will reach the goal set by the State. In new Tangshan there already have been 220,000 families to possess an apartment that has all the necessary furnishings with good lighting and ventilation. Children older than 13 years can have their own bedrooms. The unreasonable old living conditions such as having three generations living in a single room, and one toilet and one kitchen shared by several households have been eliminated.

The coking and gas-making plant and the heating and power plant in the new district have been put into production and the original power plant has been completely renovated, the underground gas in the mine pit of Kailuan Mine has been developed, and the centralized heating and gas supply in the urban district has been achieved. So the practice of cooking with coal by each family has been completely eliminated and so, fire making and rising smoke coming from households has been eliminated as well. To use energy reasonably, most of the households in the new buildings have electric water and gas meters.

Each inhabited area is to have a population of 30,000-50,000 people and each inhabited area will consist of 4-5 sub-areas. For each sub-area there will be department stores and cultural and health care facilities to serve the people. In addition, a number of cadre-living apartments have been built each with a living space of 70-125 m^2.

At the center of the city a comprehensive shopping center has been set up with a department store building 14,000 m^2 in area, 5 times bigger than before the earthquake. In addition, a 5-story service building has been built with a floor area of 38,000 m^2 to sell hardware, electrical appliances, chemical products, cloth, medicine, and books for family use. The largest song and dance theatre in the city is also located nearby. Among the big-sized buildings a ring-shaped comprehensive commercial market is built there including a commercial park which includes a rice fragrance village; a ceramics store; a furniture store; a candy, cigarette and wine salesroom; and a cold drink and tea house all distributed in a 2-story building. In the central square a small park with some small buildings will be built with an artificial pool and small bridge. In summary, it has features of the Dongfeng Market of Beijing and Chenghuang Temple of Shanghai and it breaks the old pattern in which the store buildings are laid out along the streets.

There are two big hotels more than 10 stories high on the west side of the commercial center. To the south stands a green post office building and to the east a workers' hospital 9 stories high. The beautiful scenery of Fenghuang Hill Park can be seen in the distance (Fig. 2).

Several institutions are located north of the commercial center between Fenghuang Hill Park and Jianshe Street such as office buildings of the City Committee of CPC, the city government, the Tangshan City Library, the Coal Mine Medical College, and the Teachers Training College. Further toward the north there will be a physical cultural center and a number of gymnasiums and stadiums.

To green the city and improve the environment the natural conditions of Dachengshan Hill and the Douhe River to the east of the urban district are utilized and a large natural park has been planned. The park will separate factories from living quarters.

Harnessing of the "3 wastes" in the industrial area of Tangshan City has already reached State standards. The serious polluter, the Tangshan No. 2 Steelworks, has not discharged any more contaminants after being renovated. A separate sewer system for rainwater and for polluted water was built. The 5 newly built sewage treatment plants can handle 306,000 tons of polluted water daily and the polluted water handled by the 2nd grade treatment in the plants will be clean enough for irrigating farmland. The sanitation conditions in the city proper have been greatly improved by the new sewer and the new centralized heating and gas supply system.

Before the earthquake the roads in Tangshan City were narrow and winding. There were too many T-shaped crossings and there were too few streets going out of the city so traffic was very inconvenient. Aiming at solving these problems several measures were taken: widening the road surface, increasing the number of traffic trunk-lines, strengthening winding roads and continuing streets through the T-shaped intersections. As a result, a traffic system linking all directions was formed. The width of the main trunk roads was widened from 30 m to 40-50 m, the sub-trunk roads were widened from 20 m to 30-35 m and branch roads widened from 3-6 m to 10-20 m; 7 ring-like intersections were built and 27 new trunk roads and sub-trunk roads were completed. There were 8 trunk roads with a width of more than 40 m for which a 3-piece plate structure (see Photo 1) was designed and built; the roads were divided into 2 lanes, an express lane and a slow lane. The original railway line from Beijing to Shanhaiguan was shifted out of the urban district so it now runs through the western part of the city. In addition, a new railway station was built at the terminal in the west part of the city.

II. The Reconstruction of the New Tangshan

During reconstruction of the new Tangshan special attention was given to seismic resistance from planning, site selection, and engineering design and construction. Generally speaking, it can withstand an intensity VIII earthquake without damage and intensity IX and X without buildings collapsing. The standard of defense for common buildings is on the basis of intensity VIII which is stipulated by the State. Lifelines will have an enhanced earthquake resistance.

1. Planning for residential quarters

The site for living quarters should be selected to avoid poor geological conditions as much as possible. In the section where geological conditions are better (Class I or II) residential buildings of 4-6 stories can be built, and in those sections where geological conditions are poorer (Class III) it would be better if no buildings were constructed, but if necessary 1-3 story buildings could be considered.

The density of residential buildings should be limited. In general, for 4-6 story buildings the space between two buildings is 1.7 times the eaves' height and architectural density of residential buildings is 21%-27% of the land area with a story height of 2.8 m.

Generally speaking, the net population density for 4-6 story buildings is 800-1,000 people per hectare so it is in accords with the State stipulated standards of 900-1,000 people per hectare.

On the basis of statistics of 18 sub-areas with similar facilities the land area used for dwelling and living is 15-24 m^2/person, the average is 18.43 m^2/person for floor area which is 8-15 m^2/person; the average is 11.01 m^2/person. Public buildings have 3-6 m^2/person in general, the average is 5.08 m^2/person; green land is 0.2-1.5 m^2/person, an average of 0.76 m^2/person; pavement in sub-areas is 1-3 m^2/person with an average of 1.84 m^2/person. The building area for each family is 46-52 m^2/household, the average residence has 6.32 m^2/person. It is a little higher than the State standards stipulated in 1985, i.e. 5 m^2/person, so it is one of the highest dwelling levels presently in China.

The arrangement of land used for dwellings, green land, and roads is helpful to disperse the population. During the Tangshan earthquake 3-6 story buildings often collapsed at 2/3 their total height. A design consideration is that when 2 close neighboring buildings collapsed simultaneously it is proper to keep 5-6 m of open space for people to escape. The green land area should be 6 m^2 per person by either beautifying the environment or offering a refuge space for the inhabitants when a destructive earthquake occurs. The paved streets in the sub-area should be straight and water supply facilities should be equipped near each of the green-lands.

During the reconstruction of the new Tangshan available land was scarce and there were some difficulties with the government taking over land to do construction in a short period of time, so the bend of the Douhe River was selected for construction of the sub-area residential buildings where the geological conditions were poor and subject to soil liquefaction. The Hebei Living Quarters and Diaoyutai Living Quarters are located here. In the design the footings were enlarged to reduce loading per unit area to prevent a building from cracking due to uneven sinking of the ground. In addition, some structural measures were taken to reinforce the buildings. To prevent damage from landslides along the Douhe riverbank a zone of 60-80 m

along the riverbank was used as a protection-belt with no building on it. The ground under the buildings near the protection-belt were rammed by a 10-ton rammer so as to improve their bearing ability.

2. The type of structure for residences

On the basis of experience from the Tangshan earthquake there are 2 main points to be made in choosing the structure type of residential buildings:

(a) To decrease the building's weight to reduce earthquake loading when an earthquake occurs.

(b) To prevent damage from fragility and try to enhance the ductility of the structures.

In light of the practical conditions of either the building materials or the construction contingents of Tangshan City, the 3 mainly structure type of the buildings should be:

(a) pouring inside, hanging outside and pouring inside, laying outside;

(b) brick-concrete structure with structural column;

(c) frame and light-plate structure.

(1) Pouring inside, hanging outside and pouring inside, laying outside

Pouring inside and hanging outside means the exterior walls and interior walls are poured-in-place reinforced concrete. No plaster coating on the wall is needed. Elements such as floor slabs, kitchens, toilets, spacing board, outside wall panels, stairs, and balconies are all prefabricated and finished at the component's plant. When installed no finishing is needed. The progress rate was greatly quickened with construction practiced in this way. This construction pattern was adopted for the No. 1, 3, and 4 Hebei sub-areas in the downtown district; the No. 42, 44, 45, and 48 Zhaozhuang residential areas; the No. 31, 40, 56 sub-areas; the B area on Jichang Road; the No. 6 and No. 9 sub-areas in the Fengrun New Area; the No. 4 sub-area in Tangjiazhuang; the east mining area; and so on (see Photo 2).

Pouring inside and laying outside means the outside wall is laid with brick but the other elements are the same as hanging outside. This structure costs less and the insulating property of the outside wall is good so the 4-6 story residential buildings that were built later such as Nos. 24 and 25 in the downtown district, the A area in the area of Jichang Road, and the Longdong and Shuidong sub-areas were mostly built in this way (see Photo 3).

(2) Brick-concrete structure with structural columns

Buildings made with brick have been a traditional construction practice in China for several thousand years. Experience shows that brick houses can not withstand the shock force of an intensity VIII earthquake. The Tangshan earthquake showed that reinforced concrete bond beams at each floor level and spaced vertical beams in brick walls markedly improved earthquake resistance. Under high intensity shaking, even though the brick walls are cracked, a building can remain standing. In common situations the anti-shearing capacity of the brick

masonry is improved, even though such structural columns and beams do not act as main load bearing members due to the containment actions of the columns and beams. On the other hand, when the brick structure has been broken the wall will change from rigid to flexible but it can keep the building from collapsing. During the rebuilding of the new Tangshan buildings under 4 stories which were brick-concrete structures had structural columns built in at the 2 ends of the load-bearing wall. Furthermore, the bond beams were built both on the upper and lower boundary of the load-bearing wall connecting with the structural columns. Thus, the anti-seismic behavior has been improved and material expenses and construction costs have not increased much. To build dwellings like this the weight of steel bars used was only 15-18 kg/m^2, while for the structural patterns of pouring-in and hanging-out or pouring-in and laying-out the weight of the steel bars was 25-30kg/m^2 of building area. For the cost of the civil construction the former is 100 yuan or so per m^2 while the later is 110 yuan.

(3) Frame and light-plate structures

This structure is light in weight of materials, less in dead weight and rigidity as well as it is long in free-vibration period so it is not easy to produce resonance in the epicenter area. That is, it is helpful in the reduction of quake disasters. But through the practices of a number of buildings it is clear that the cost of this type of construction is higher than any other so it has not been widely used in residential buildings and it is only adopted in some public multi-story buildings with longer spans.

3. Industrial buildings

Most of the industrial buildings were reinforced concrete or steel structures. Among them, single-story buildings were row structures and most of the multi-story buildings were frame structures. Though these buildings had not been designed for earthquake forces they suffered less damage. Therefore, in constructing new Tangshan some improvements were made only in the building layout such as reducing the roof weight, trying to make the floor even and tidy, avoiding long spans, lowering the center of gravity of the buildings, making the structural layout simple, and making the torsional center of rigidity and center of gravity coincide. The single-story production houses and the inner frame multi-story production buildings which were built with brick columns in the past were now built using reinforced concrete columns. For multi-story production buildings attention was paid to overcoming their defects such as being rigid in the upper part and soft in the lower part or vice versa.

4. Chimney, water tower and stock bins

Reinforced concrete was adopted and for most of these types of structures for a few low ones a brick structure was used; these should have had structural columns to improve their anti-seismic ability.

5. Lifeline structures including water and power supply as well as communications

Lifeline engineering is closely linked with people's life safety. The seismic standards for these structures should be raised one degree of intensity more than for ordinary buildings. Their safety requirements should be to maintain their operational function during a strong earthquake.

A ring-shaped network with multi-water sources and a district-divided system should be adopted for the water supply. In addition to pumping underground water a second water source has been developed by diverting water from the Luanhe River to Tangshan. Some of the enterprises which use a large volume of water develop their own water supply. As for the native wells in villages, they should be maintained as well as possible to meet the urgent need following an earthquake. The water sources and water works should be dispersed as far as possible, a dual pipeline system should be used to connect the pump station and the water works and should have ductile connections. In addition, the design standard should be increased for key buildings and structures such as pump stations and water works. Water supply valves and underground fireplugs should be mounted in city squares and open areas of the city as a temporary water supply station when an earthquake occurs.

Multiple power supply sources with a ring-shaped electrical network should be used linking the high-voltage electricity lines of the 4 power stations of Beijing, Tianjin and Tangshan to prevent damage in one location from resulting in overall power failure. For the vital sections i.e. the transformer substation, distribution station, control cabinet and power dispatcher's office, all should be designed for enhanced earthquake resistance.

In the communication field both wired and wireless communication are combined together but equipment buildings are built separately. For wire circuits more underground cables and outlets should be installed and they should be connected in a circular and radial network. The radio room should be located in a safe place to guarantee that communication is kept working when hit by a strong earthquake.

Public security, fire fighting and hospital facilities should be reasonably distributed and be located at sites that are easily accessible by automobile traffic. Emergency relief and hospitals should be especially resistant so relief work and treatment of the injured can be provided.

In addition, various bridges, reservoirs, and river channels both inside and outside of the city have all been reinforced and rebuilt with improved seismic resistance.

Generally speaking, during the rebuilding of Tangshan seismic resistance has been carefully considered. The New Tangshan City, rebuilt on earthquake ruins, is the first anti-seismic city in China.

III. The Experiences of Rebuilding Tangshan

The rebuilding of Tangshan was a giant project with many difficulties that had rarely been seen in construction history in China or the world. The main experiences and lessons are now summed up as follows:

1. Rebuilding on the basis of self-reliance as much as possible to reduce the State's burden

A contract system in which the building funds came from future profits and tax relief was adopted for rebuilding the enterprises of Tangshan City.

2. Depending on support from all over China and organizing unified command

Under the leadership of the Central Committee of CPC 15 provinces and municipalities selected to provide manpower and materials for rebuilding Tangshan under the direct jurisdiction of the central government and PLA forces assisted in the reconstruction of new Tangshan. Topographical surveying, geological prospecting, planning, designing, and constructing was done by a huge technical contingent which came from the whole country. At the same time, under the direct leadership of the Hebei Provincial Party Committee the Tangshan City Construction Command Headquarters was set up to coordinate the rebuilding. The headquarters exercised a series of so-called "six unifying" measures i.e., unified planning, unified designing, unified construction, unified funding, unified distribution and unified administration. The results were successful.

3. Standardization for designing and industrialization for construction

During the rebuilding of Tangshan standard components were used as much as possible. By doing this both industrial production and mechanization of construction provided benefits. As a result, a good number of construction procedures and design work were made more efficient.

4. Peripheral construction first and the construction on the old city site second

After the earthquake it was difficult to get a clear path through the old city proper to prepare for construction because ruins of buildings blocked all avenues of approach. The inhabitants had no where to go so to settle this problem it was determined to first take over land at the outskirts of the city and build living quarters, then to let some inhabitants of temporary sheds in the urban district move into the new housing and thus make available space for new building sites in the city. To accomplish this some necessary decrees and compulsory means were used to guarantee that reconstruction could proceed. During this time many inhabitants rebuilt, their collapsed one-story houses by hand.

5. The rebuilding of roads and laying the pipe network in the city

Because of the urgent need for residential buildings many units started projects in sub-areas even though engineering for roads and underground pipeline networks had not started yet. As a result, because design and building of underground projects such as the water supply, drainage works, heating, power and gas piping could not keep pace with the sub-area dwelling construction, much digging out and burying of pipelines, etc. took place. This frequently caused public complaint. Thus, the dwellings in the sub-area were complete but because they were unable to offer heating and gas to the inhabitants each family had to burn coal. As a result the new buildings became dirty and the new city became polluted by coal smoke.

Photo 1. The 3-piece plate structure on Jianshe Road in the center district of Tangshan City.

Photo 2. Building site of "pouring inside and hanging outside" in the No. 71 sub-area.

Photo 3. Buildings of "pouring inside and laying outside" in the No. 24 sub-area.

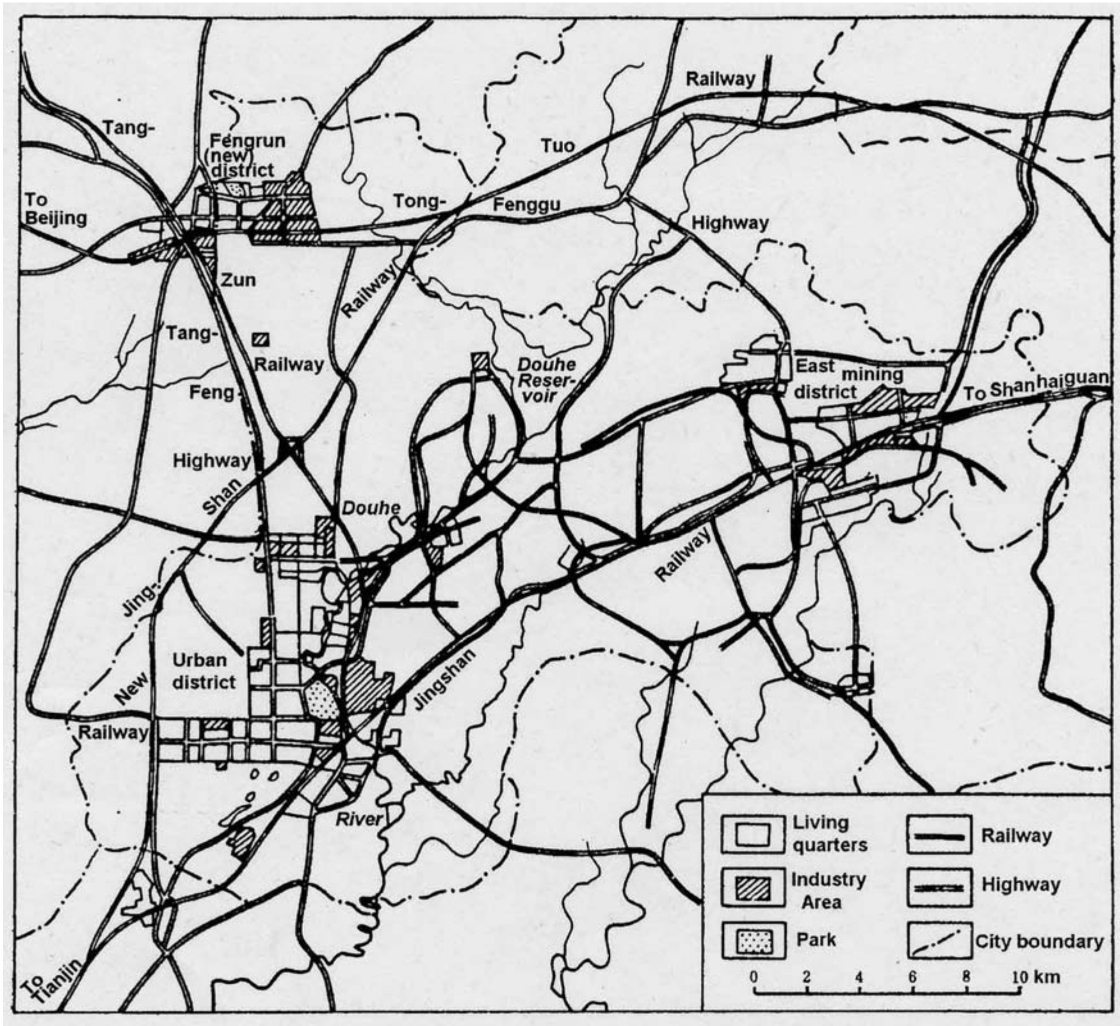

Figure 1. A sketch of Tangshan City's overall plan.

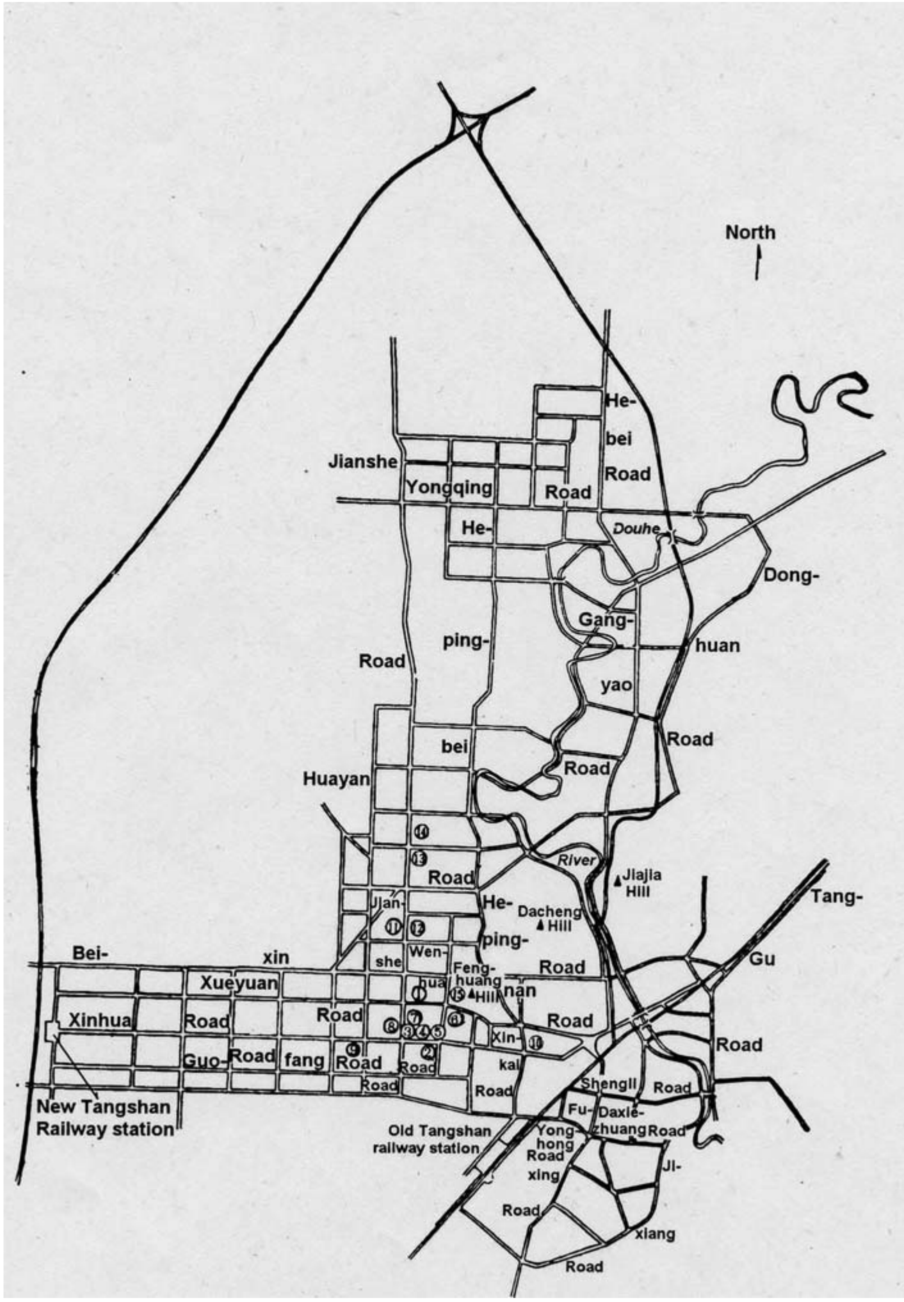

Figure 2. Planning and layout sketch of the Tangshan City area.
1. People's city government; 2. Seismic monument; 3. Department store building; 4. Comprehensive commercial center; 5. Tangshan theatre; 6. Workers Hospital; 7. City's Post Office; 8. Tangshan Hotel; 9. Agricultural Trade Market Hall; 10. Kailuan General Hospital; 11. Stadium; 12. Coal Mine Hospital attached to Medical Science College; 13. No. 2 Hospital; 14. Tangshan Guesthouse; 15. Fenghuang Hill Pa