PROCEEDINGS OF THE SECOND INTERNATIONAL CONFERENCE ON ENGINEERING BLASTING TECHNIQUE

KUNMING 1995

第二届国际工程爆破技术学术会议论文集（英文版）

Chief Editor：Zheng Zhemin

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内容简介

第二届国际工程爆破技术学术会议于1995年11月7日—10日在昆明举行。会议是由中国力学学会主办，由中国科协、国家自然科学基金委员会及中国工程爆破协会和中国力学学会工程爆破专业委员会共同协办的会议。会议代表来自澳大利亚、加拿大、中国、香港、印度、意大利、日本、朝鲜、蒙古、瑞典、美国等11个国家和地区共计150人左右。代表均为各国知名的工程师和专家。

本文集汇集了90篇文章，覆盖了工程爆破技术的各个领域，均属国内、外的最新进展和最新成果。具体内容涉及：爆破基础理论的研究、复杂环境下的建筑物拆除技术、不同室爆破技术、深孔爆破技术、特殊爆破技术、新型爆破器材、新型起爆网络、爆破安全技术及爆破测试技术等。

本文集可供冶金矿山、煤炭、地质、石油、化工、建筑、建材、铁道、交通运输、水利电力、农田基建和国防等部门从事工程爆破的科研、设计和施工的工程技术人员以及大专院校的有关专业的研究生、教师和大学生参考。

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第二届国际工程爆破技术学术会议

THE SECOND INTERNATIONAL CONFERENCE ON ENGINEERING BLASTING TECHNIQUE

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FOREWORD
——ADVANCES IN ENGINEERING BLASTING IN CHINA

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Blasting engineering has always played a prominent role in the national economic construction of our country, because, being a rapidly developing country with large resources, the scale of blasting engineering projects in China is very large. Over one million people are employed in this profession of whom about sixteen thousand are engineers and technicians. Close to one thousand establishments are engaged in the research, design, implementation and manufacturing of explosives and blasting equipment. There are about five hundred blasting engineering companies. Annual consumption totals more than one million tons of explosives and one billion and four hundred million caps. The annual gross product in money value is several tens of billions of yuan.

In pace with this development one witnesses a continual development and advancement in blasting technology. New areas are being constantly explored and the scientific and technical level advances rapidly. A brief account of this development in recent years is given below.

I. MULTIPLE CHAMBER MASSIVE BLASTING(MCMB)

This type of blasting continues to be preferred where large masses of rock(and/or soil) are to be removed because it does not require a high degree of mechanization nor skilled laborers. For these reasons this technique is widely employed.

Since 1958 MCMB has been used to build dams as part of hydroelectric projects or to contain mine tailings, debris flows or industrial wastes. There are now more than sixty such dams in use. Experiences gained through such projects have resulted in a set of comprehensive and practical design methods. From 1985 to 1990 a concerted effort involving a team of scores of experts was made to study the feasibility of building high dams using this technology. More than one hundred technical reports were written covering theoretical studies, new design concepts, methods of implementation, control over percolation, geotechnical problems, optimization through the use of computers, etc. This joint study helped advance MCMB technology to a new level.

There is now a tendency toward replacing concentrated charges by line charges placed in tunnels. Engineering practices show that the latter scheme when properly employed brings about more uniform breakage of the rock mass and indicates a more efficient use of explosive. A series of in-depth study has been carried out at the Chinese Academy of Railway Sciences involving both model tests and numerical simulation. This study provided useful insight with regard to wave action and the dynamics of breakage when the line charge is of finite aspect ratio. Formulas for calculating the amount of charges have been developed by a number of research and design establishments.

A problem of major concern in chamber blasting is the size distribution of boulders in the muck because oversized boulders would require secondary blasting which is to be avoided as much as one can. It is well known that at distances sufficient distant from the charge yet sufficiently close to cause fragmentation of the rock mass, fragmentation usually takes place along weak joints, seams, fissures already existing in the rock. At such places, which are a major source of oversized boulders, the size distribution is determined by structure of the rock rather than the amount of charge itself. Therefore, to limit the amount of secondary blasting, it is necessary to make these regions as small as possible.

The Beijing Graduate School of the Chinese University of Mining has made a series of interesting studies on the fragmentation of rock under the action of a detonating line charge which shed light on what actually takes in the rock during blasting. The theoretical framework is based on damage mechanics and theory of fractals.

From the 60s to the 80s directional blasting was employed to build dams for various purposes. One major problem is that the slopes created as part of the crater are usually fragmented and, therefore, unstable. It is quite costly and time consuming to have them stabilized. Moreover, since the amount of charge is proportional to at least the cube of the length scale of the project, such a design is not feasible for building high dams. Following Gregorian, the Institute of Mechanics took a radically different approach according to which explosive charges would be designed only to loosen the hillside and cause an artificial landslide, thus decreasing by nearly one order of magnitude the amount of explosive required. At the same time damage done to the slope would be much reduced. Model tests done in the laboratory and numerical simulation indicate that this approach is indeed promising, although much developmental work remains to be done.

Three multiple chamber massive blastings each making use of about ten thousand tons of explosive were carried out in the last few years. One of them was designed and implemented on December 28, 1992, by the Nanjing Institute of the Army Engineering Corps. The total amount of charge used was twelve thousand tons and the amount of rock blasted was 10,850,000 m^3. The whole project from design to completion took only 90 working days. This project made use of multiple layers and multiple banks of explosive charges without decoupling and fired in sixty rounds with millisecond delays. This project was considered to be of high quality and high speed.

II. DEEP HOLE BLASTING

Deep hole blasting technology received a big boost after China imported and developed large modern drills and explosive chargers. Tall bench, deep hole blasting technology has made significant progress. At the Nanfen iron ore mines, bore holes 250 mm in diameter are used together with wagon chargers. It has been reported that at a single shot, there can be 505 bore holes with a total charge of 274 tons in 104 rounds, yielding 810 thousand tons of ore. The electric shovels work at 1,921 ton/hr and the over size rating does not exceed 0.035%.

This technology is now also widely used in cutting rock foundation in highway construction. Since highways often go through residential areas, care must be taken to avoid disturbing the inhabitants and to prevent ground shocks due to explosions from damaging houses. Usually this places a limit on the number of firings and stringent requirements on controlling ground shocks. A recent example is the construction of an express way through a village where a deep cut(14m) 400m in length and 30m wide had to be made. Many recently constructed modern residential houses are located within 100m of the site, the closest being only 10m away. Only one firing was permitted. By adopting a series of measures such as millisecond delay firing and pre-slotting, the project turned out to be very successful. None of the houses suffered from damage.

Progress has also been made in smooth blasting, pre-slotting and water infusion blasting.

The Three Gorges Project is now underway. This huge project involves an enormous amount of rock cutting, foundation and steep slope work. Deep hole blasting will be used a lot, often under stringent conditions. It is expected that this project will help advance greatly deep hole blasting technology.

III. URBAN EXPLOSIVE DEMOLITION

In keeping with rapid urban development in recent years, there is an increasing demand to reconstruct plants and tear down outdated buildings. Urban explosive demolition technology meets this demand.

Since the early 80s following the implementation of the policy of reform and opening to the outside world, the scale of demolition blasting has been huge. At the Shijingshan Power Plant complex a total of 50,000 m^3 of structures had to be dismantled. In the demolition of the Beijing Chinese Overseas Hotel which was an eight story, 34m tall concrete reinforced masonry building located in down town Beijing, over 6,000 bore holes and 600 kg of explosives were used, producing about 3,000 m^3 of debris. Non of the surrounding buildings close by suffered from damage nor was the traffic obstructed.

In recent years more tall buildings have been torn down by means of explosive demolition technique. A prominent example is the 12 story building in the down town area of the city of Fuzhou. Most of the buildings demolished were of reinforced concrete framed structure. So far there has been no demand to tear down steel framed high rise buildings.

For the demolition of reinforced concrete structures, there exists now in China a complete set of design methods to ensure success of the demolition. Some companies have developed their own CAD system. In addition, there are also successful examples in the use of water infusion blasting and sequentially fired folding demolition blasting. It may be said that the explosive demolition technology developed in China appears sufficiently mature to assure safety and to meet design requirements.

IV. UNDERWATER BLASTING, EXPLOSIVE TREATMENT OF UNDERWATER SOFT SOIL, EXPLOSIVE SHAPING OF UNDERWATER DRAINAGE HOLE

Many rivers, especially the Yellow River and Yangtse Rivers, dump huge quantities of soil onto the sea board. The Yellow River switched its course and outlet to sea many times in recorded history. As a result a large section of China's coastal line is deposited with a thick layer of soft soil with little carrying capacity. In harbor construction special attention must be paid to the proper treatment of this soil bed used as structural foundation. Since 1985 the Institute of Mechanics has engaged in a study to treat underwater soft soil by explosive means. Several novel methods have been developed which include the explosive displacement of soil and simultaneous dumping of boulders down to the clay bed (EDSSD), explosive compaction, and explosive displacement of soft soil under a pre-laid rock pile. In addition to studies on mechanism, scaling rules and formulas for calculating the amount of charge, a set of procedures have been developed to enable successful implementation of these methods in engineering practice. Since 1987 the EDSSD method has been widely promoted and so far more than 20 break waters and dikes have been successfully built this way, among which the largest project completed was the 6.77 km long dike at the Lianyungang harbor, scoring a saving of about 30 million yuan out of a total investment of 170 million yuan.

EDSSD has the following additional advantages: shorter construction period, greater consolidation of the body of the dike (or whatever the case may be), structurally more stable, smaller settlement. Therefore by conventional standards the same dike can be designed with a smaller cross section, thereby at a reduced cost.

Eleven projects to cut and shape drainage holes under reservoirs by explosive charges either in chambers or in bore holes have been completed. Such a project was carried out in 1994 at the Miyun Reservoir at a water depth of 34 m. Hydraulic model test showed that there was no need to build a special trap to retain the debris as what is conventionally done. This idea was in incorporated in the design which turned out to be very successful. This design saved both time and investment.

V. R & D AND THE PRODUCTION OF EXPLOSIVES AND EQUIPMENT

Powdered AN\TNT is the explosive most often used. Recently, non-ionic surfactant and reactivated oil phase substances have been successfully produced as additives to reduce dust, to make the explosive damp proof and to prevent caking. The production of such explosives reaches now more than 300 thousand tons annually.

Several series of emulsion explosives were successfully made in the 80s. These explosives are safe, of low cost, and possess good explosion and water resistant properties. They are being used in more than twenty provinces. The annual production now exceeds 200 thousand tons. The Beijing General Institute of Mining and Metallurgy has set up production plants in Mongolia and Khazakstan.

The Wuhan Institute of Safety succeeded in producing high precision microsecond detonating caps up to 60 delays, caps without primary explosive and other special purpose caps. Aside from satisfying domestic needs, some are sold abroad. China holds patent rights over caps without primary explosive in USA, Russia, Sweden and Australia. Through technology transfer with the Swedish Nobel Co., a production line with the capacity of making 25 million such caps has been set up.

In the 80s explosive mixing and charger wagons were imported and are very popular in many mines.

VI. SAFETY AND MANAGEMENT

In blasting engineering safety must always be assured. Aside from independent studies in various institutions, the state has organized large scale tests to gather data on ground motion, blast waves, flying rocks, noise, the diffusion of explosion products, etc. These data form a firm basis for safety evaluation.

Based on systematic studies three codes have been issued, namely "Codes on safety for blasting", "Codes on safety for massive blasting", and "Safety codes with regard to urban demolition blasting". At the same time standards for the qualification examination of engineering blasting operators have been published. These measures play a critical role in improving safety management and in reducing explosion accidents.

In China, before a blasting project is to be implemented, a special examination on safety is required. This procedure played an important role in the explosive demolition of the concrete wall (originally built to prevent water seepage) in the Gezhouba coffer dam. In this case the amount of charge was 47.8 tons fired with 324 delays. Safety measures taken assured that the power generating units already installed were absolutely secure.

In order to promote scientific and technical exchanges on engineering blasting, the Society of Engineering Blasting was founded in The early 80s within the Chinese Society of Theoretical and Applied Mechanics. This society has sponsored one national scientific and technical conference every four years and published five proceedings. More recently, in order to improve management of the profession, the Chinese Association of Engineering Blasting was formed. There are four national publications, namely, "Explosion and Shock Waves", "Engineering Blasting", "Blasting" and "Blasting Equipment". Together, they cover subjects from the theoretical to the practical.

Chinese experts actively take part in international cooperation and exchanges. By learning advanced experiences from abroad, we hope to continually push the technology of engineering blasting to still higher levels.

INTRODUCTION TO LARGE-SCALE COYOTE BLASTING IN ZHUHAI PAOTAI MOUNTAIN

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Abstract The key to the success in large-scale blasting operation is to iron out the contradiction between the engineering requirements and natural conditions on the premise of the safety of operation. This paper introduces the successful experience of 10 kiloton blasting in Zhuhai Paotai Mountain, which was conducted under unfavourable natural conditions and achieved successfully by choosing a reasonable program, implementing a safe and accurate plan, analysing the damage influence, and taking prevention measures. The following intended results have been reached:

- A single blast removed 10,852,000 m^3 of rock
- Throw ratio was 51.36%
- Direction of throw were controlled, with a few flyrocks within the range of 300m
- In the residential districts farther than 600m, no damage of houses happened

I. MAIN DATA OF THE OPERATION

1.1 Site Description

Paotai Mountain is located in the south of Sianzhao island, Zhuhai, China, and is surrounded by sea in three sides; the coast is gentlely sloping with reefs and sandy beach; the depth of the sea is 1 to 2m. The mountain is 800m long in E-W direction, and 500m wide in S-N direction. The highest peak is 107.00m a.s.l. with another two hilltops of 47.16m a.s.l. and 66.32m a.s.l. in the east and sides of the ridge. The average slope ranges between 10° to 30°. Rock in the blasting area is mainly a secondary plutonic with no large tectonic disturbances and stratigraphy shows a cover layer, 1 to 3m thick, of red subshale, followed by amphybolic granite with different degree of weathering. S.G. is 2.64 to 2.66 g/cm^3 and compression strength 174 to 250MPa. There are earth roads on the north side; residential areas are 600 and 1000 m away.

More than 10 buildings stand on the mountain, and three underground structures beneath with a total length of 609m.

1.2 Engineering Requirements

The rock volume required to be shock blasted above 4m level, with a single blasting operation, is $1085.2 \times 10^4 m^3$; of the total volume, 50% has to be thrown away by the blasting. No damage to the surrounding people, buildings and residential areas is allowed. Premature blasts, long fires, unexploded or partly exploded charges should be excluded. The project