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Guidelines for Civil Structures Demolition Method Selection to Enhance Environmental Protection

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ABSTRACT

This article introduces and explains the demolition methods used for civil structures. There are two types of techniques for demolition, dismantle and damage. The conventional and non-conventional methods are used in the demolitions of steel, paving and reinforced concrete structures. It is clear that there are many factors and requirements affecting the processes of demolitions. It is concluded that many factors including the environmental protection, disturbance, solid waste generated, space, cost, safety of workers and surroundings, energy required and other factors are very important in selection of the demolition process. It is appear that the nonconventional methods used in concrete construction's demolition are effective, fast, costly and environmental safe. These methods have also many environmental benefits such as reduced air contaminants and noise pollution.

Key words: Demolition, Conventional methods, Nonconventional Methods, Environmental pollution and Solid Waste Management.

1. INTRODUCTION

Development in countries and cities needs certain types of buildings and sometimes reconstruction and demolitions of the old concrete constructions [12]. Concrete structure has its own life period. Usually the life of concrete is ranged from 30-90 years and it depends on many factors. Demolitions are defined as procedures to remove, dismantle, and destroy buildings [30].

Figure 1: Demolition of the concrete buildings.

Concrete buildings demolitions need to be evaluated correctly in addition to strong plans before the demolition procedures. Demolition operations need also special plans to treat and dispose of the quantities and types of solid waste produced. Demolition management plan should also contain an assessment of potential environmental pollution generated in the area of demolition process is taking place [1].

The building demolition procedures must comply with local governmental regulations and controlling acts. Usually regulations and guidelines are applicable whenever the demolition is needed. High precautions and requirements should be adopted and measured to mitigate the environmental effects due demolition's operations [1]. Mitigations the effects on the environment are including noise and vibration abatement, solid waste management plan, dust management, hazardous waste management plan and all must have measurable procedures describe as eco-friendly measures and sustainable.

Figure 2: High precautions and requirements should be adopted during demolition's operations.

Civil structure demolition is associated to many environmental concerns such as location, noise disturbance, solid waste, dust dispersion, hazardous waste, energy consumption, transportation, landfilling and water pollution [23] & [16]. All mentioned parameters and other affected factors are increasing the costs of demolitions executions processes and as a results the environmental and healthy

requirements need more budget [18]. For example, in the European United countries spending up to 50 percent of construction costs on repairing, rehabilitations and demolition processes [6].

Demolition processes usually produce huge amount of metal, plastics, concrete and other materials as a solid waste. Therefore, management plans, recycling, reuse and other ideas are of concerns to minimize the pollution to environment. For example, reuse of recycled solids and concrete waste produced as solid wastes were utilized in improvement of pavement mixtures [7] & [2]. As a result new methods of demolitions are required for many reasons relating to time, cost, environmental pollution and noise effects.

Figure 3: Civil structure demolition is source for many environmental pollutions.

2. OBJECTIVES

This article is constructed to classify the demolition methods and equipment or devices used. This paper will introduce to the reader the cost, safety, advantages and disadvantages of each method, so one can choose the proper method for demolition works associated in different civil constructions.

3. DEMOLITION

Demolition is any work associated with damage or disassemble the components of any civil structures which comply with the national or international regulations. Usually demolition works don't including the works of removal or disassemble of utilities pipes, sewer lines or electricity wiring and devices ….etc.

4. DEMOLITION TECHNOLOGIES

Buildings, civil concrete structure, concrete bridges need to be damage or demolition for many reasons. Violation of rules and regulations, deterioration of the civil components (40 -90 years) [19], old structures, development of some area and new safety and healthy requirements are some of the reasons to redesign or reconstruction of this concrete structure. Therefore, demolition is needed to be applied upon these civil structures to damage them for the above reasons. Concrete is a combination of different material that involves essentially of a binding compound (Cement), within which is an embedded element of aggregate, usually a combination of fine and coarse aggregate. Depends on that, this structure has many properties which gave it the consolidation and high bonding between its mixtures components. Therefore, many methods have been used for breaking, demolition and damaging whenever these structures are unfavorable or unwanted. Demolition methods were classified as conventional and non-conventional technologies. Description of each method provided in the following sections which will help in processes selection [26].

4.1. Conventional Demolition Technologies.

4.1.1. **Demolition by hand.** Usually, workers and technicians are using hammers, breakers, and saws to demolish and dismantle the concrete or steel structures by this method.

4.1.2. **Controlled Blasting.** This method is suitable for demolition of the large or huge structure of concrete or heavily-reinforced, thick concrete sections by making a hole in the structure's body and then fired the explosives inside [21].

4.1.3. Wrecking Ball or Wrecking Slab. The equipment is a ball or slab of 2 to 5 tons usually hanging by crane boom and swinging to hit a non-reinforced or lightly reinforced concrete structures as shown in Figure 4, below, [25] & [4].

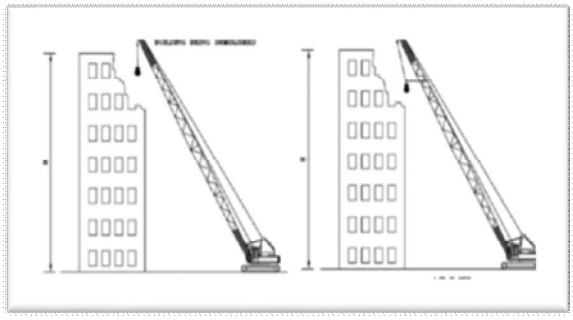

Figure 4: Wrecking Ball using in demolition.

4.1.4. **Air and Hydraulic Rams.** In this type of demolition, the processes are usually achieved by means of hydraulic machines such as hydraulic excavators with all required Accessories [9].

4.1.5. **Thermic Lance.** Thermal lance is used to cut any metals or materials in nuclear construction. This process produces huge amount hot gases and harmful

smoke. These vapors have to be controlled and collected to prevent environment pollution [26].

4.1.6. Rock Splitter. The demolition or damage of concrete by this method depends on smashing the structure by hydraulic expanding in a hole until the damaged happened; this method is mentioned in a research paper for [13]. The figure shows the detailing of the rock splitter for demolition : A- general aspect of the three parts of the stone-splitter; B- cross-section; C- inserting stone-splitters in the rock; D- putting oil between the wedge and the feathers facilitates the sliding. Rock Splitter method is explained in the following procedures which are illustrated in Figure 5.

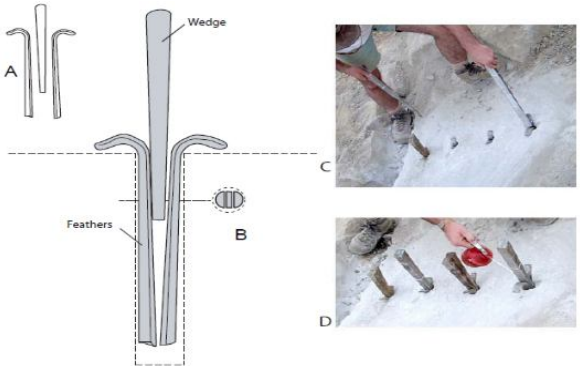

Figure 5: Rock Splitter technique using in demolition.

4.1.7. Bristar Demolition. It is a non-explosive agent for concrete structure demolition. The mixture of material is prepared by mixing with water. The material is expanded in the holes of the concrete structures or inside rocks cracks and creates high pressure inside until fractures happen. This method is described as eco-friendly, a low-pollution, high-safety, and low-cost method. Bristar chemical technique used in demolition is shown in Figure 6.

Figure 6: Bristar chemical using in demolition.

4.1.8. **Wall & Floor Sawing.** The method is used for low disturbance requirements in the work areas. Especial type of cutting metals are used in making a grove along the concrete body By using this method, the maximum thickness of wall or floor which could be cut is up to one meter.

4.1.9. Core Stitch Drilling. The demolition is occurred by a hole made in the concrete structure by using diamond or an electric rotary drill to develop the cracking and damage, many researches discussed and introduced the method in their works such as clear in Figure 7, [20].

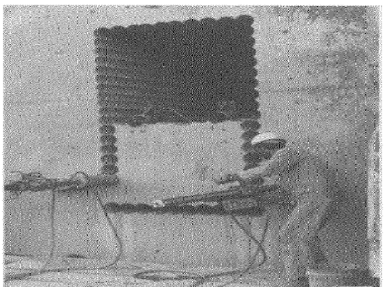

Figure 7: Demolition by using Core Stitch Drilling.

4.1.10. Explosive Cutting. Explosion method for demolition is achieved by using explosive materials putting in different places in the concrete structure to accomplish the damage. This method is describe as an unsafe method and costs a lot in comparison with other methods, [10] & [24].

4.1.11. F1ame Cutting. It is a separation process of the concrete components by using flame with a temperature of approximately 16500 ^{o}F. The method is used when the effects of vibration of the demolition processes are high.

4.1.12. Paving Breaker and Chipping Hammer. The paving breakers are a steel part used to cut and dismantle the concrete or paving structure by the means of hydraulic fluid forces or pneumatic forces moving in a reciprocating motion. [29].

4.1.13. **Drill & Spa11.** The mechanism of this method is summarized in that the drill makes a hole of 1-2 inches in the structure with 3 inches deep in the surface of concrete while the spall develop the spall in the structure till the contaminated surfaces removed without demolishing the whole structure. This method used for small areas.

4.1.14. Scarifier. The scarifier is an equipment operated hydraulically suitable for removal of dirt and deposits from the surface of concrete structure which is needed to be reused again.

4.1.15. **Water Cannon.** Different mechanical devices are used for removal of contaminates from the surface of concrete structures by using either high water jets techniques or glycerin guns [8]**.** One example is shown in Figure 8, below.

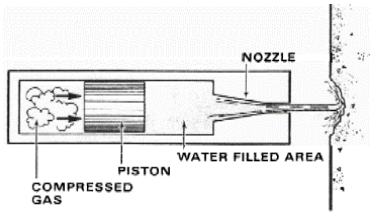

Figure 8: Water Cannon technique using in demolition.

4.1.16. **Grinding.** It is a method of removing the surface thin layer of concrete structure by abrading the surface by grinder. The grinding machine is shown in Figure 9.

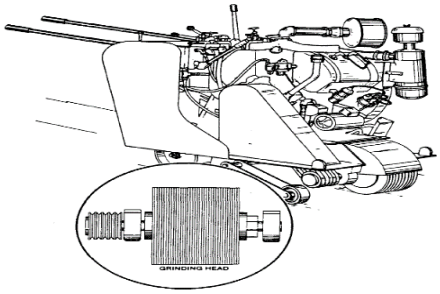

Figure 9: Grinding machine used in demolition.

4.2. Conventional Demolition Technologies.

As a result, new demolitions technologies are required but they have to protect the environment first. So these demolition technologies have to improve demolition safety requirements and prevent pollution. Green technologies of the demolition of the building are usually used to improve safety and reduce pollution. Therefore novel eco-friendly green demolitions technologies are needed, some of them were mentioned in the research of [9]. The following demolition methods descriptions are detectable as non-conventional demolition methods in most references and researches.

4.2.1. Electric heating method. This method is used for demolition recently. It based on the heating of the reinforcement elements inside the concrete structure to achieve the demolition works, [14] & [11].

4.2.2. **High-voltage pulse technology.** An electrical discharge is one of the latest technologies in the demolition and destruction of the concrete structures. The technology is based on the principle of electrical discharging into a channel to breaking and cracking the structure. This method describes as a low cost, environmentally safe and long-time cycle in comparison with conventional demolition methods, [17].

4.2.3. Chemical explosive agent. The demolition of the concrete structure is done by non-explosive materials by fracturing. Different circular holes are made in the concrete structure and the expansion materials are bored inside the holes for a certain time then the structure is cracked as shown in figure 10 below, [15].

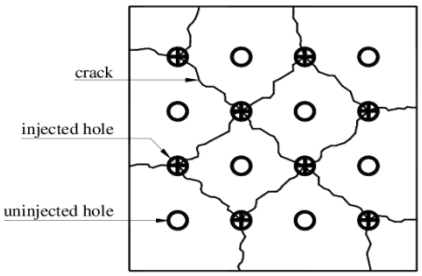

Figure 10: Chemical explosive agent used in demolition.

4.2.4. **Resonance demolition method.** This method still in the beginning and testing, resonance of the material is the factor for demolition process where the damage may be occurred based on the disturbance of resonance of the material itself. [28] & [9].

4.2.5. **Cut & down construction method.** This method is suitable for demolition of the high-rise concrete structures. The process of dismantling of the structure is starting from down to top. First floor is the basic area of the process where the removal of all components other than the columns used the area of this floor until the task is achieved, [22].

4.2.6. Drilled core demolition technology. Where the reinforced concrete structure is with dense steel inside, then this technique is suitable and fit for use. Demolition is done by make holes inside the concrete structure without cutting the steel bars of the structure. Finally the debris is removed by trucks and loaders. [3].

4.2.7. Intelligent robot demolition technology. Robot is used recently in the demolition of the reinforced concrete in dangers situations where the orientation of robot is achieved by controlling devices away from the demolition locations. [5].

5. SAFETY, COST AND ENERGY REQUIREMENTS FOR DEMOLITION TECHNOLOGIES.

The demolition processes are usually selected depending on many factors such as energy required for the demolition works, the entire cost of the process, the time needed for achievement, concrete structure type, machines, tools, worker safety, environmental requirements and solid waste management procedures to be applied. An attempt was done through this paper to construct two matrixes to describe each demolition technology for the purposes selection. Therefore, Table 1 below shows the summary of the conventional demolition technologies features and requirements. While, Table 2 represents the nonconventional demolition technologies features and requirements.

Table 1: Summary of Conventional Demolition Technologies Features and Requirements.

Demolition Method	**Practices [Concrete Thickness Application]**	**Production Rate**	**Advantages**	**Dis-advantages**	**Relative Equipment Cost**
Demolition by hand	Floors, pavements, slabs and roofs.	5-16 m^3/ day	Ease to operate, high mobility	High pollutants, high dust, low safety.	Low cost.
Controlled Blasting	≥ 2.2 feet up to 8 feet heavily-reinforced concrete Depend on the structure.	5-500 yd^3/day	High thicknesses cutting.	High noise and shock, high dust and area contaminations	High cost (Depend on reinforced concrete).
Wrecking Ball or Wrecking Slab	≤ 2.8 feet, bridges, steel structures, factories, silos Heavy Ball up to 5-6 Tons. Need height of 20 feet above the structure.	6-80 yd^3/day	Ease to operate, skilled workers are needed.	Dust during demolition. low safety	Moderate cost
Air and Hydraulic Rams	≤ 1.8 feet	20-40 yd^3/day Depends on specification of rocks and concrete structure.	lower noise, lower vibrations,	limited access structures , nuisance and dust	40-60 $/yd3
F1ame Cutting	≤ 4.8 feet Up 60 inches with or without reinforcing rod	One square foot per hour of working area	lower noise, lower vibrations,	High temperature is needed up to 16000°F. High heat and heavy smoke pollution.	$180 per square foot
Thermic Lance.	Remove or cutting materials in nuclear plant. To do holes, slots, grooves up to two inches up to 3.5 feet depth.	Cutting speed 20- 40 cm/min.	lower noise, lower vibrations,	Flame temperature from 2200 to 5000°C. Generates high smoke and very hot gases.	Moderate cost.
Rock Splitter.	In limited access areas (hospitals, schools …etc.),	200 m^3/day	Low noise , Ease to operate, high mobility	Dust, Low safety for workers.	Moderate cost
Bristar Demolition.	Chemical expansion in holes in structure	10-20 hours the pressure reach 4300 psi into the holes. The fracture will be from 0.25 to 2 inches.	No noise , Ease to use, high mobility, lower vibrations,	Low safety for workers.	5 $ for each 2 inch dia hole per foot of hole depth.
Compound Wall & Floor Sawing	Partially removal of some part of old structure. Up to 3 feet thicknesses	0.07-0.65	Low dust, moderate noise, ease of operations	Slow production rate,	High cost. 8-25 $/$ft^2$ for I inch depth.
Core Stitch Drilling.	To remove cylindrical section of the non-reinforced concrete structures.	Each hole up to barrel of 200 liters. 4 in – 4 feet / hour.	Low noise area,	Very slow production	Costly (17 $ / ft of 1.5 in dia up to 550 $/ft of 24 in dia holes.
Explosive Cutting.	For the especial geometry concrete structure and for the situation when more cuts are required.	Depend on the area and other affective factors in the process	Effective, massive destruction.	High noise, and dust. Reinforced concrete needs more workers to cut steel	$14.00/ft for 300 grains/ft to $64.00/ft for 2200 grains/ft
Paving Breaker. & Chipping Hammer	Up to 1 ft thickness, to remove asphalt and concrete.	2 workers produce 20 yd^3/day	For removing of concrete from small area, easy to operate	Noisy, dust and contaminants are generated during the process of demolition. Low safety for workers.	75 $ / yd^3
Drill & Spa11	Removal of contaminants from structure. up to 5 cm thicknesses (holes of 5 cm dia and 8 cm depth and center to center of 30 cm on the structure),	7 m^2 / hour	Low dust and contaminants	The procedures is ease to normal workers to do.	50 $ / m^2
Scarifies.	Thin layers up to 1 in thickness of contamination on the structure surface.	5 yd^2/ hr	Materials are reused after demolition, easily operate.	High dust and contaminants,	7 $/$ft^2$
Water Cannon.	Up to 3-4 spall with 0.8 in diameter	4-10 ft^2/hr	High quality of demolition works	Need killed operator, low safety on workers,	High cost.
Grinding.	Thin layers of contaminated surfaces (paint, sealers, erosion deposits). Up to 1 in deep.	1000 ft^2/day	Good quality of removal	Highly dust production and contaminants , Low safety,	35 $ / yd^2

Table 2: Summary of Non-Conventional Demolition Technologies Features and Requirements.

Process	Practices	Production Rate	Advantages	Disadvantages	Cost of Demolition
Electric heating method.	Reinforced concrete structures.	0.1-0.15 m^3/hr.	Reuse of damaged material, low noise, low dust and safe method on workers.	Expensive, need high power, thermal effects.	High cost
Chemical expansive agent.	Metal structures, steel columns and piles.	Depend on the structure size, hardness of steel and the removal parts orientation.	Low dust, low vibrations	Very expensive, skilled workers are required, lower safety.	Very high
High-voltage pulse technology.	Demolition of concrete structures in dense populated areas.	Depends on the current, voltage uses	Low dust, low vibrations, no noise no contaminates generated.	Very expensive, skilled workers are required, lower safety.	Costly
Resonance demolition method.	Small parts	Depends on the frequency of radiations of the metals to be removed	Low dust, low vibrations, no noise no contaminates generated.	Very expensive, skilled workers are required, lower safety.	Costly
Cut & down construction method.	Demolish small parts of the concrete structures.	About 0.03 m^3/hr.	Efficient method, safe to the environment, no contaminates no noise, no vibration, safe to adjacent places, recycling the damaged materials.	Skilled workers, Power required, expensive	Costly
Drilled core demolition technology.	Removing of steel bars from reinforced concrete structures.	Depends on number, length and diameters of bars in meter cubic of the structure.	Low dust, low vibrations, no contaminates generated, smoothness surface of demolition.	Accessibility is high, no need to kills in operators, lower efficiency.	Low cost
Intelligent robot demolition technology.	In cases of dangerous to work in , nuclear contaminations incidence	Depends on the situation of works.	It depends on the mission required.	Need especial requirements. And high skilled operators.	Costly

6. CONCLUSION

Demolition materials consist of different solids such as concrete, soil, steel, and other metals. These materials, in general, are unusual and generated different environmental problems. Explosive or implosion demolition is the most preferred method for safely and efficiently demolishing the larger structures which requires a very high precision. The nonconventional demolition methods are very expensive in comparison with conventional methods. New and efficient methods for demolition or dismantling concrete or civil structures in dangerous situations were introduced recently. Such methods are called nonconventional demolition technologies; one example is intelligent robot demolition technology. Selection process of demolition is always based on many factors such as time, cost, structure type and size, hardness of concrete, production rate, workers safety, environmental conditions and pollution produced.

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