Ultrasonic Testing of Concrete Cracks in Large Diameter Bored Piles Based on Crack Characteristic Database and Analysis of Causes of Cracks

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Abstract: the cast-in-place pile is deeply buried in the ground, so cracks are difficult to detect. As an important civil engineering material, concrete is very important to control the engineering quality. However, due to the characteristics of concrete itself, damage will inevitably occur. Among all kinds of defects that cause damage to concrete structures, the most common one is cracks. If the construction quality is strictly controlled and some targeted technical measures are taken to reduce the occurrence of cracks, the quality of the project can be well guaranteed. Ultrasonic wave belongs to elastic wave, which is one of mechanical vibration propagation forms. Using the principle of phase inversion of the first wave of the longitudinal wave in the ultrasonic wave, the crack depth of the concrete component can be detected successfully. In this paper, from the concept of concrete cast-in-place pile, combined with the crack characteristic database and ultrasonic detection technology, the concrete cracks and the causes of cracks in large-diameter bored pile are analyzed.

1. Introduction

With the development of our country's economy, the number of high-rise buildings, super high-rise buildings and long-span structural bridges in urban construction is increasing, and the demand for high-strength concrete is increasing [1]. In many important infrastructure and large-scale civil engineering structural projects, under the interaction of harmful factors such as long-term effect of structural load and environmental erosion, the engineering structure will inevitably suffer strength attenuation and damage accumulation [2]. This has led to various defects in concrete structures, and the ability to resist normal environmental effects and sudden natural disasters has obviously decreased. In extreme cases, catastrophic accidents are prone to occur suddenly, resulting in significant economic and property losses and casualties [3]. Among all kinds of defects that cause damage to concrete structures, the most common one is cracks. Due to the influence of various factors, concrete construction will inevitably produce construction cracks, which not only leave hidden dangers to the project, but also may cause major economic losses due to the scrapping of the project [4]. The safety, durability and bearing capacity of concrete members are all related to cracks. In order not to damage or avoid damage to concrete structures to the greatest extent, nondestructive testing methods are mostly used for crack detection, among which ultrasonic method is the main one [5]. Acoustic waves are widely used in the quality inspection of concrete houses. One of its important functions is the ability to observe the depth of concrete cracks.

The initial micro-cracks often lead to continued cracking, so visible cracks appear. These cracks will have an important impact on the durability and bearing capacity of the concrete structure [6]. The crack will directly affect the bearing capacity, service life and durability of the structure [7]. In order to determine the damage of the crack and formulate the corresponding remedial measures, it is very important to determine the depth of the crack [8]. As there are many factors that affect the construction quality of cast-in-place piles, strict requirements must be imposed on each link in the construction process, and various influencing factors must be considered in detail. Reasonable control of concrete cracks is of great significance to ensure the quality of construction projects and improve the durability of structures. Ultrasonic physical simulation is an important means to understand the wave field and reveal the characteristics or laws of wave field changes. It is also an important direction of structural model experimental research at present [9]. Underground engineering piles are not convenient for surface observation, so this paper analyzes the causes of

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concrete cracks and cracks of large-diameter bored cast-in-place piles based on crack feature library and ultrasonic detection technology.

2. Basic Theory of Ultrasonic Crack Depth Detection

If we want to deal with the cracks of cast-in-place piles correctly, we must understand the causes of the cracks. When the concrete composition material, process conditions, internal quality and test distance are certain, the measured values of acoustic parameters such as the speed of ultrasonic wave propagation in the concrete, the amplitude of the first wave and the frequency of the received signal should be basically consistent. When strong dislocation or even rupture occurs in elastic medium, disturbance can be considered to be formed, and the disturbed area constitutes a wave source. The concrete of cast-in-place pile body is affected by itself and other surrounding factors, the changes of humidity and temperature, and the constraints of foundation environment, all of which will bring great influence to cast-in-place pile and easily produce cracks. It does great harm to buildings. What is more serious is that it can deteriorate the structural stress state, destroy the integrity and impermeability of cast-in-place piles, and threaten the safe operation of buildings [10]. There will be a special kind of wave on the interface of different media. It exists on the interface of different media and is called surface wave. When concrete has defects, ultrasonic wave will reflect and refract in the process of propagation. Relatively speaking, the high frequency component decays faster than the low frequency component. The change of the received signal frequency can also be used as a parameter to judge the existence of concrete defects. Even slight cracks will have an impact on the durability and aesthetics of the building, and become serious cracks over time. There are many reasons for the cracks, and the objective causes are very complex.

A good concrete mix proportion should meet the technical requirements of concrete. Including durability requirements such as crack resistance, frost resistance, chemical resistance, etc.

A major multipurpose railway bridge was built across the yangtze river in china,the foundation of the mainbridge is designed with diameter of 2.5m and c35 under water concrete boring cast-in – palce pile, see table 1 for the concrete mix ratio to be controlled in this constrction after testing and empirically verification.

Table 1 the Concrete Mix Ratio Data(C35)

Cement index	Cement	Sand	Gravel (coarse)	Gravel (Fine)	Admixture	water	Fly-ash
Ordinary silicon hydrochloric acid cement	430	772	616	406	5.16	170	\
P.O 42.5 Low alkali	251	803	721	309	3.87	155	136

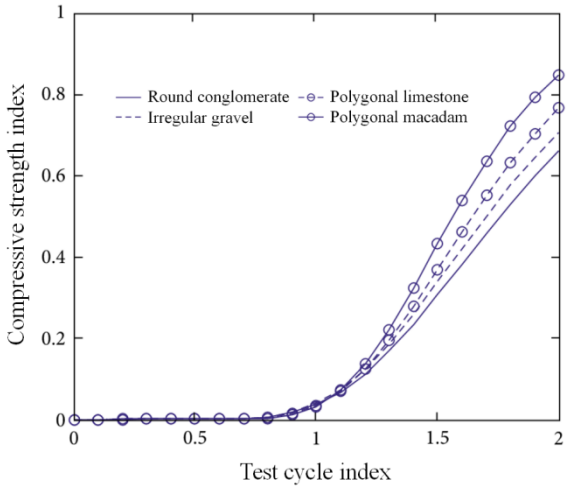

Fig.1 Relationship between Compressive Strength and Age of Concrete Prepared with Different Aggregates

Coarse aggregates are divided into pebbles and crushed stones according to their sources of production. Pebbles have a smoother surface than crushed stones and have smaller void ratio and total surface area. Gravel surface is rough and angular, with better adhesion to cement slurry than pebbles. The types of coarse aggregates have different effects on the strength of concrete. The influence of aggregate decreases with the increase of water-cement ratio, because the strength of slurry itself plays a major role. The relationship between compressive strength and age of concrete prepared with different aggregates is shown in figure 1.

Ordinary concrete uses cement as a cementing material. Cooperate with sand, stones, and water in a certain proportion. Artificial stone, which is hardened under certain curing conditions after mixing and molding. Strength is the most important technical property of hardened concrete. The strength of concrete includes compressive strength, tensile strength and flexural strength. The compressive strength is the basis for determining the strength grade of concrete. When preparing concrete, the factors affecting durability are the homogeneity and stability of the mixture. As well as the compactness of hardened concrete, the formation of a centromeric network, the interface structure, dimensional stability, and the quality of the raw materials used [11]. High quality and well graded aggregate can improve the compactness of concrete, thus improving the workability of fresh concrete and the strength and durability after hardening. Under the same mix ratio, the higher the cement strength, the higher the concrete strength. When the cement strength is fixed, the strength of concrete mainly depends on the water cement ratio. When the water cement ratio is large, the strength of cement stone is low, and the strength of concrete also decreases. The mix proportion design method mainly considers improving the internal structure of concrete, improving the durability and prolonging the service life of the structure.

3. Concrete Cracks of Large Diameter Bored Piles and Causes of Cracks

3.1 Impact of Environmental Factors

Even if the concrete itself is of good quality and the material ratio is also good, if it is placed in a harsh environment, cracks will occur in cast-in-place piles. The sound wave that does not travel across the crack propagates in a straight line, while the sound wave that travels across the crack needs to travel around the end of the crack to form a broken line, and the propagation time is prolonged. Reinforcement restricts shrinkage, but it cannot prevent shrinkage. Its restraining effect on the shrinkage of reinforced concrete will cause tensile stress in the concrete and cause compressive stress in the reinforcement. In the bridge substructure, measures for adding structural steel bars are adopted to make the structural steel bars function as temperature bars, which can effectively improve the crack resistance of concrete. When performing ultrasonic seismic physical simulation experiments, in order to make the kinematic characteristics of the simulation experiment results similar to the fluctuation characteristics of the prototype, the size of the model must be proportional to the prototype. This basic principle is the principle of geometric similarity. Proper structural reinforcement can increase the ultimate tensile strength of concrete, and has a positive effect on controlling temperature shrinkage cracks and shrinkage cracks of concrete. A steel bar obstruction similar to the structure is arranged at the position before receiving materials or pumping to pass at the required speed. Concrete that cannot normally pass through the device is considered unqualified for filling. In some cases with special requirements or complicated reinforcement, the filling property of concrete mixture determines its hardened quality. Therefore, a filling inspection shall be conducted before pouring. The mass loss rate of concrete under different cycles is shown in Table 1.

Table 2 Mass Loss Rate of Concrete under Different Cycles

Cycles	5	20	40	60	80	100	120	140
Loss rate	0.06	0.09	0.13	0.17	0.12	0.15	0.18	0.20

On the assumption that the sound speed of concrete tested across joints is basically the same as that of concrete not tested across joints, the depth of cracks is calculated according to the difference

of sound propagation time. The mechanical properties of concrete include compressive strength, tensile strength, ultimate tensile value, elastic modulus, volume deformation, etc. Ultrasonic wave belongs to elastic wave. Except for frequency difference, the propagation law of ultrasonic wave in medium is almost identical to that of elastic wave in medium [12]. During the concrete pouring process, the hydration reaction of cement will release a large amount of heat, causing the internal temperature of concrete to rise and a temperature peak to appear at a certain age, after which the temperature will drop. By analyzing the characteristics of ultrasonic waves, we can see that the propagation of ultrasonic waves involves mechanical parameters such as displacement, density, velocity and pressure of particles [13]. The volume deformation of the cement itself is closely related to the mineral materials in the cement, and the positive and negative values of the volume deformation of the cement are directly related to the cement varieties. Environmental impact is various, such as the construction of cast-in-place piles in relatively cold weather and humid environment, which are easy to form cracks.

3.2 Influence of Material and Construction Technology

The thermal properties of concrete include specific heat, thermal conductivity, thermal conductivity, thermal expansion coefficient, adiabatic temperature rise, etc. Concrete is heterogeneous, so the ultrasonic wave does not propagate in a straight line. On the crack interface, the acoustic resistance changes abruptly, and the waveform changes at the end of the crack. The shrinkage stress of temperature is directly related to the coefficient of thermal expansion, and the lithology of aggregate is closely related to it. The variety of cement and the mix proportion of concrete directly affect adiabatic heating.

Low construction technology is another important reason for cracks in cast-in-place concrete piles. Some engineering concrete raw material quality is very good, but in the raw material mixing, transport, casting mistake invisibly caused the concrete quality, strength deterioration. The selection of ordinary cement and low-heat cement and the proportion of cement in concrete have different influences on the probability of cracks, including temperature stress. Ultrasonic testing technology is the most important means to detect cracks in cast-in-place piles. By emitting high-frequency ultrasonic waves, the location of cracks is detected. Unreasonable structural form, too large volume, and the existence of a large number of holes will lead to more stress concentration areas in metropolitan structures, which has laid a considerable hidden danger for the formation of cracks.

4. Conclusion

It is a simple and effective method to detect the depth of concrete shallow crack by ultrasonic wave, but it also has some shortcomings. The measurement error caused by reinforcement cannot be ignored. Ultrasonic testing technology is the most important means to detect the crack of cast-in-place pile. Even if the quality of concrete itself is good and the material ratio is also good, but if it is placed in a bad environment, it will also cause cracks in the cast-in-place pile. In the process of concrete pouring, the hydration reaction of cement will release a lot of heat, which makes the internal temperature of concrete increase and temperature peak appears in a certain age, and then the temperature drops. In the physical model experiment, the distance between the transmitting point and the receiving point for each movement can be appropriately increased until the phase inversion of the first wave is found, and then the measuring point is encrypted. Concrete is heterogeneous, so the ultrasonic wave does not propagate in a straight line. On the crack interface, the acoustic resistance changes abruptly, and the waveform changes at the end of the crack. Sometimes, due to the limitation of on-site detection conditions, the detection accuracy of the method of detecting vertical fracture depth by asymmetrically arranging receiving points is not as high as that of symmetrically arranging measuring points. Therefore, symmetrical arrangement should be applied preferentially to detect crack depth.

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