Research on rolling fatigue testing for manhole covers

Zhonghua Su\textsuperscript{1,*}, Xiang Yu\textsuperscript{1}, Zhangcheng Yang\textsuperscript{1}, Hongbin Nie\textsuperscript{2}, Jian Ou\textsuperscript{3}

\textsuperscript{1}Chongqing Institute of Metrology and Quality Inspection, Chongqing, China
\textsuperscript{2}Bridge Engineering Co, Ltd of China Railway First Bureau Group, Shanxi, China
\textsuperscript{3}Chongqing Zhongtian Electromechanical Technology Co., Ltd, Chongqing, China

*Corresponding author e-mail: su\_water@163.com

Abstract. Some manhole cover accidents have been listed. The direct cause and root cause of manhole cover accident have been analyzed. Anti-rolling fatigue testing for manhole covers has been put forward and studied. Test parameters and decision methods have been determined. An equipment for manhole covers anti-rolling fatigue testing, which including equipment structure, equipment parameters, manhole cover installation structure and equipment operation, has been studied and designed.

1. Introduction

There are many kinds of manhole covers in our cities. According to material, they can be divided into cast iron manhole covers, steel fiber concrete manhole covers, cement manhole covers, silicon plastic manhole covers, resin manhole covers and polymer mould killing manhole covers. According to purpose, they can be used for electric power, electric credit, radio television, heating, water supply, drainage, gas and property, etc\cite{1-2}. With the development of urbanization, manhole covers safety accidents happened frequently. On December 4, 2018, a manhole cover falling accident happened in Guanlanyundi Residential Area of Hangzhou, which resulting the death of pregnant woman and july fetus. The accident reason is broken manhole cover. On March 16, 2017, a cleaning aunt fell manhole cover and dead in Modern Forest Town Guanggu Avenue of Wuhan, which was resulted by manhole cover flip. On September 22, 2018, a truck lost control and rolled over in a culvert of Yuci East Outer ring Road, which was resulted by missing manhole cover \cite{3}. A lot of injuries happened for manhole covers. According to the statistics of Shandong Business Daily, from January 2014 to July 2016, 72 times manhole cover injury accidents were reported in Shandong province. Of these, 27 times were caused by missing manhole covers, 19 times were caused by loose manhole covers. The loose manhole covers appear to be intact, once stepped by passers, unimaginable accident will happen. Other manhole cover injuries were caused by manhole covers damage and the unevenness between manhole covers and roadside, which often lead to falls of passers and cyclists \cite{4}.

Frequent manhole cover safety accidents seriously threaten people's life and property safety. The direct causes are manhole covers losing, manhole covers damage, wrong using of manhole covers, manhole covers slipping, manhole covers flipping, the unevenness between manhole covers and roadside, the broken pavement around manhole covers, etc. The root causes are manhole covers management, manhole covers installation and surrounding road construction, manhole covers quality, etc. Manhole covers management problems are mainly reflected on unclear liability subject, imperfect system for inspection, maintenance and replacement, unclear compensation standard for liability subject, and imperfect mechanism for supervision and management, these results of buck-passing and difficult
claim after accidents [5]. Settlement, bulge, poor rolling resistance road is the main installation and surrounding road construction problems, which shortening service life and increasing safety accidents of manhole covers[6]. The quality of manhole covers is affected by standard, which mainly depends on material quality, design quality and manufacture level. Some spot checks of manhole covers have been head in CHengdu, SHanxi and Hunan in 2015. The percent of pass was less than 90, and bearing capacity was the most frequent failure [7]. Appearance, structure size and bearing capacity have been put forward in GB/T 23858-2009《Manhole Covers》, but no requirement for rolling fatigue performance. Rolling fatigue damages of manhole covers are the main failure in engineering application. So, rolling fatigue tests method and device of manhole covers have been researched focus in this paper.

2. Anti-rolling fatigue test method for manhole cover
Rolling fatigue performance was not required in existing manhole covers standard. Dynamic fatigue tests requirements were put forward in some standards and references [8]. Without research theory of rolling fatigue test method for manhole cover, research idea of simulating reality has been adopted in this paper. In practical application, damages of manhole covers are related to their position and specification, wheel loading, and rolling frequency. There are three relations between manhole covers surface and road surface, higher, equal and lower. When manhole covers surface higher, horizontal impact load on the edge of manhole covers, which lead to their edge damage and middle warping. When two surfaces equal high, minimal damage will happen on manhole covers, such as best installation. When manhole covers surface lower, vertical downward impact load on their surface. The corresponding impact load is \( F = M(2hg)^{0.5}/t \), which is directly proportional to wheel loading and height difference between manhole cover surface and ground, and inversely proportional to impact time. FIG 1 shows that, manhole cover surface lower than road surface, early damage has happened for vertical downward impact load.

According to the requirements of 《Specmcations of Cement Concrete Pavement Design for Highway》 (JTJ 012-94) [9], standard load of road is 100 kN per axis, and corresponding wheel pressure is 50 kN. Obviously, load requirement of road is far lower than that of manhole covers. According to the standard GB/T 23858-2009《manhole cover》, manhole covers have been divided into six grades, and the static pressure load and using place have been shown in table 1 [10]. The rolling fatigue detection method for manhole covers has been studied to determine their rolling life. Load, mode, time and qualified standards of rolling should be clarified before test, as shown in table 1. Rolling load and rolling times of manhole covers are different in different service environments, so deepening research has not developed in this paper, only rolling fatigue detection method has been studied.
Table 1. Using site and test parameters of manhole cover

| category | A15 | B125 | C250 | D400 | E600 | F900 |
|----------|-----|------|------|------|------|------|
| Static load F/kN | 15  | 125  | 250  | 400  | 600  | 900  |
| Use place | Greenbelts, sidewalks and other areas where motor vehicles are not allowed. | Sidewalk, non-motorized driveway, car park and underground parking lot. | Residential areas, back streets, areas with only light vehicles or cars. | Urban main roads, highways, high-grade highways and other areas. | Freight stations, terminals, airports and other areas. | Airport runway and other areas. |
| Rolling load F/kN | / | \(F_b\) | \(F_c\) | \(F_d\) | \(F_e\) | \(F_f\) |
| Rolling-number N/Times | / | \(N_b\) | \(N_c\) | \(N_d\) | \(N_e\) | \(N_f\) |
| Eligibility criteria | / | no crack | no crack | no crack | no crack | no crack |

3. Rolling fatigue testing equipment for manhole covers

3.1. Structure of test equipment

A detection device for manhole covers has been designed according to their rolling fatigue detection method, which including electric motor, rotary disc, push and pull arm, wheel frame, wheel shaft, wheel, guide rail and manhole cove. See figure 2 for details. Driving force for wheel is provided by electric motor, which driving rotating disc by belt or chain. One end of push-pull pendulum arm is rotated and connected with connecting shaft of rotating disc, and the other end is rotated and connected with connecting shaft of wheel frame. Wheel axle is through fixed by wheel frame. The safety and stability of moving wheel and wheel frame has been ensured by sliding block placing in guide rail. The sliding block is fixed on lower end of wheel frame. The moving direction of wheel frame needs to be changed after it running to the left and right dead center, which will have a serious impact on the service life of electric motor and push-pull swing arm. So, buffer springs have been set at the left and right dead center to reducing running impact and reverse starting load. Four buffer springs have been fixed on four guide rails respectively and acted on sliding block directly. The guide rails have been bolted to horizontal ground, and the manhole cover to be tested will be installed between them.
3.2. Test equipment parameters
Choice of electric motor mainly depends on designing maximum rolling load of testing equipment. The diameter of rotary disc and length of push-pull pendulum arm mainly depend on the maximum size of manhole covers. According to standard GB/T 23858-2009, the maximum size of manhole covers is 900mm. In order to ensure wheel doesn't get in touch with manhole cover before rolling in and after rolling out from it, the minimum distance of wheel reciprocating rolling should reach 1100mm, the diameter of rotating disc has been designed as 1200mm, and the length of push-pull swing arm has been designed as 1300mm. Loading zone has been set on wheel frame and axle. Load on axle should be loaded symmetrically onto both ends. Load on wheel frame should be loaded evenly into weight bin. Guide rail length, and width between two guide rails need satisfy inspection and installation requirements of manhole covers. The length and width is 3000mm and 1200mm respectively.

3.3. Installation structure of manhole cover
Hole for installing manhole cover seat has been set in ground between two guide rails. Metal manhole cover seat, sized (co)600mm, 700mm, 800mm and 900mm, have been designed according to manhole cover size. According to manhole cover size to be test, corresponding metal manhole cover seat has been selected for fixing installation. Then install manhole cover into manhole cove seat to finish installation before testing. See fig.3 for detail manhole cover installation structure.

3.4. Test equipment operation
After manhole cover installation, rolling load and running time are set on testing equipment as required detection parameters. After electric motor running over, the rolling fatigue test for manhole covers is completed.

4. Conclusion
Causes of manhole covers accident have been analyzed. The direct causes are manhole covers losing, manhole covers damage, wrong using of manhole covers, manhole covers slipping, manhole covers flipping, the unevenness between manhole covers and roadside, the broken pavement around manhole covers, etc. The root causes are manhole covers management, manhole cover installation and surrounding road construction, manhole covers quality, etc. Aiming at the quality of manhole cover, anti-rolling fatigue testing of manhole covers has been put forward and studied. Test parameters and decision methods have been determined. Manhole covers anti-rolling fatigue testing equipment, which including equipment structure, equipment parameters, manhole covers installation structure and equipment operation, has been studied and designed. The successful application of this method and equipment can improve the quality of manhole covers, and reduce the accidents of road manhole covers.

References
[1] Li qianyang. Discussion on the construction of safety management system of urban cellar manhole cover [J]. Exploration and observation, 2017 (13): 36.
[2] Dai sunfang. Research on real-time monitoring and information management technology of road manhole covers [J]. China municipal engineering, 2016(6): 104-105.
[3] The traffic accident on the east outer ring road of yuci was teased by netizens as "project quality" [N]. Yellow River News Network, 2018. 10.02.

[4] In shandong, 72 manhole cover injuries occurred in three years, and 15 children were killed [N]. Shandong Business Daily, 2016.07.27.

[5] Wang jin, Yang kexin. China reference experience from foreign cellar cover management methods [J]. China management informatization, 2018 (11): 172-174.

[6] Wang Ben, Huang Mengjiao, Zhu Chenlin and others. Study on the influence of pit cap on road traffic [J]. Industry and Technology Forum, 2015 (13): 78-79

[7] Peng bin, Xu yingcheng, Ning xiuli et al. Safety and Risk analysis of manhole cover quality [J]. Standard science, 2016 (6): 62-66.

[8] Hu xiaobo, ZHang yanchun, Yang yuanxia, et al. Study on Fatigue Test and Application Grade of Steel Fiber Reinforced Concrete Inspection Cover [J]. Journal of Building Materials, 2003 (2): 200-203.

[9] JTJ 012-94, Code for design of highway cement concrete pavement [s].

[10] GB/T 23858-2009, Manhole cover [s].