Indexed in
Scopus Compendex and Geobase Elsevier,
Geo-Ref Information Services-USA, List B of Scientific
Journals, Poland, Directory of Research Journals

International Journal
of Earth Sciences
and Engineering

www.cafetinnova.org

ISSN 0974-5904, Volume 09, No. 05

October 2016, P.P.2327-2332

Analysis and Damage Inspecting Technology of Supporting Structure in Deep Foundation Pit Construction

RUI YANG AND SHENGLI YUAN

Department of civil engineering and architecture, Xinxiang University, Xinxiang, Henan 453003, China

Email: *xxxy_tjy@163.com*

Abstract: In order to reduce the supporting failure rate and to improve the performance of damage inspecting of supporting structure in deep foundation pit construction, the structure analysis based fractional algorithm and damage inspecting system is proposed in this paper. Theoretical analysis of static and dynamic structural responses of the deep foundation pit structures after repairing and strengthening are adopted by using SAP2000 Ver. 14.2.0 software. The results of theoretical analysis of static structural response shown that the values of tensile stresses are decreased about 50%, and the values of vertical deflection are decreased comparing with the values before strengthening, indicating that the strengthening methods are effective to improve the structural performance of the deep foundation pit structures.

Keywords: *Evaluation standard; damage inspecting technology; supporting structure; deep foundation pit construction*

1. Introduction

Along with our country urbanization speed up the pace of construction, urban construction land supply has become increasingly scarce, as a result, the use of underground space more and more get the attention of people. But factors such as the depth of deep foundation pit, excavation cycle long and big influence on the surrounding buildings, complex geological conditions, frequent accidents become restricts the effective use of underground space [1]. In order to seek better and more reasonable way of foundation pit supporting, cantilever pile, pile support, anchor piles, steel piles, underground continuous wall, cement-soil retaining wall and soil nailing wall were used through the experience summary and theoretical derivation. Pile anchor bracing for excavation depth, no restriction of excavation width, and the advantages of large equipment can be used for the excavation is becoming more and more get the favor of designer. Support scheme of pile anchor in deep foundation pit based on the application of universality in the design and calculation of uncertainty, it is necessary to analysis and research this kind of support scheme. The development and utilization of underground space is inevitably to deep excavation. In the area of foundation pit, the physical and mechanical parameters of soil have much randomness. The traditional fixed value analysis method has not considered the randomness of these parameters and therefore the results of this method will have some uncertainty. Reliability-based analysis method can consider the randomness of these parameters and the correlation between them fully. So the results of this method will be more objective and according with the actual [2-3]. At present, the reliability research of foundation pit is still in the initial stage and the main research results are concentrated on the shallow foundation pit supported with simple supporting system. But the reliability research of deep foundation pit supported with complex supporting system is in the blank stage basically. Objective analysis of deep foundation pit in the excavation process all kinds of stress changes, and the resulting changes in the surrounding environment, which has important practical significance and academic value [4].

There are different methods of repairing method which are used to improve the static and dynamic structural performance of the certain foundation repairing and strengthening structures. For foundation pit structures, the repairing and strengthening methods of the deep foundation pit structure includes repairing the deep foundation pit pavement, replacement of all the expansion joints, treating the bearing, application of chemical grouting method for treating the cracks, strengthening the top floor of box girders by using steel plates, and strengthening the main span of T-shape cantilever structure by using external pre-stressing tendons [5-6]. For deep foundation pit, the repairing and strengthening methods includes the treatment of the cracks, thickening the web of box girder along the deep foundation pit length and adding internal pre-stressing tendons in the thickening web, and constructed reinforced concrete cross beams (diaphragms) between two box girders of the deep foundation pit structure. The methods of repairing and strengthening are needed to be discussed [7].

This paper introduces several kinds of supporting forms commonly used in foundation pit firstly, emphatically describes the basic construction of support structure of the pile anchor and design method, and the calculation method of seismic and

#02090571 Copyright ©2016 CAFET-INNOVA TECHNICAL SOCIETY. All rights reserved.

non-seismic soils stress. Again the first to arrive in foundation pit excavation of foundation pit deformation observation data as the basis, using Matlab software to write retaining piles under earthquake action and non-seismic internal force and displacement calculation program, calculation result will be compared with the measured data analysis, to verify the applicability of the "m" method and the reliability of the program design. Then using finite element analysis software SAP2000 Ver. 14.2.0 for the pile anchor supporting structure numerical simulation analysis and the excavation process, and its structure and programming calculation through comparison between calculation results and measured knot stick, to verify the effectiveness of the pile anchor supporting structure and the reliability and efficiency of the finite element analysis software [8].

2. Overview

Increasing tensions in the urban land situation, often encountered in the existing buildings surrounding the deep excavation, and the facilities to do the supporting structure. As both the knowledge of engineering problems and the theory research develops a lot of new excavation problems have turned up. However, the further consideration for the original questions is still being carried on. Slope soil stress state by the state of earth pressure at rest and gradually turned to the active earth pressure state, leading to the supporting structure inside the pit displacement, horizontal displacement of the larger sphere of influence leading to pit the ground subsidence [9-10]. In addition to this settlement the size of the excavation depth and scope, but also relate to the type of foundation pit, surrounded by geological conditions and the deformation size of the supporting structure. Although the excavation have been carefully designed in advance, but because of the pit there are many uncertain factors in the soil and the theory for excavation is not enough perfect, so the city started construction of the tunnel near the building ultra-deep foundation pit research is necessary.

The damages of the deep foundation pit structure can be classified as a four types. The first type is surface damage which has surface scrapes and small nicks; this type does not need to repair. The second type is minor damage which has isolated cracks, nicks, and spalls and this type needs to repair [11]. Pile anchor bracing for excavation depth, no restriction of excavation width, and the advantages of large equipment can be used for the excavation is becoming more and more get the favor of designer. Support scheme of pile anchor in deep foundation pit based on the application of universality in the design and calculation of uncertainty, it is necessary to analysis and research this kind of support scheme. This type can be reduced the structure life. The fourth type is severe damage which includes exposed and damaged pre-stressing tendons and reinforcing steel along with loss of important cross section. This type needs repair and strengthening. Generally, the damages occur in pre-stressed concrete deep foundation pits under corrosion of pre-stressing tendons, loss of expansion joints, stains, spilling of concrete.

Deep excavation engineering is a huge systematic project. It is designed both to ensure the safety of retaining structure and to reduce engineering cost. In order to harmonize the relationship between the cost and reliability of engineering, the optimization design of retaining structure for deep excavation was born. Many problems exist in the optimization design, for example, 1. The optimization design of retaining structure usually comes down to a great lot kind of design variables and combination variables, including continuously variable and discrete variables. 2. The relation between optimization target and design variables is relatively complex. Since the sensitivity of design variables towards optimization target are abhorrent, it is difficult to establish the dominant relationships between them. The traditional fixed value analysis method has not considered the randomness of these parameters and therefore the results of this method will have some uncertainty. Reliability-based analysis method can consider the randomness of these parameters and the correlation between them fully. As a result, to search for an optimization algorithm is the key. For the sake of the optimization design of retaining structure, its contents involve primarily the following aspects [12-14]:

(1) It is necessary to establish the optimization design model for retaining structure of deep excavation.
(2) The calculation method of earth pressure for different retaining type is described.
(3) The mechanical model for retaining structure of deep excavation was set up.
(4) A new optimization method based on genetic algorithm for solving this model is presented.

Figure 1 shows a diagram of a deep foundation pit and figure 2 shows its' supporting structure.

***Figure 1**: A diagram of a deep foundation pit*

***Figure 2**: The supporting structure of a deep foundation pit*

Cracks are common exhibition of concrete deterioration and it is a major topic with several complex facets. Cracks can be caused by many factors such as loads applied during construction or in-services condition, foundation movements, temperature changes and gradients, shrinkage and creep of concrete. Generally, there are two types of cracks. The first type is known as non-structural cracks which can be observed in the deep foundation pits and overpass structures. This type can be caused by thermal expansion and contraction of concrete, contraction of concrete during curing process, change in temperature, and corrosion of steel reinforcement. The second type is known as structural cracks which are caused by dead and live load stresses.

3. The model and the algorithm

Pile anchor bracing for excavation depth, no restriction of excavation width, and the advantages of large equipment can be used for the excavation is becoming more and more get the favor of designer. Support scheme of pile anchor in deep foundation pit based on the application of universality in the design and calculation of uncertainty, it is necessary to analysis and research this kind of support scheme. Figure 3 shows the structure diagram for the supporting structure of a deep foundation pit.

Instantaneous acceleration is the change in velocity (dv) divided by the duration of the interval (dt). It is mean that the derivative of the velocity vector as a function of time. The relationship between acceleration, velocity, and the time can be shown in the following equation.

The basic equation of fractional algorithm is shown as the equation (1):

$$(N, sk) \leftarrow Key(1^k) \qquad (1)$$

This formula is used to generate file checksum parameter which is denoted by:

$$r \leftarrow \{0,1\}^k; sk \leftarrow \{e, d, r\}; \quad Output\{N, sk\}; \qquad (2)$$

The Euler function is:

$$\phi(N) = (p-1)(q-1) \qquad (3)$$

Then choose an integer e to satisfy the following equation 4:

$$\begin{cases} 1 < e < \phi(N) \\ \gcd(e, \phi(N)) = 1 \end{cases} \qquad (4)$$

Then finally export (N, sk) in Tag algorithm, we can get the optimization equation (5):

$$(T_0, T_2, \ldots T_{n-1}) \leftarrow Tag(pk, sk, m) \qquad (5)$$

The formula generates labels for each file block. The relationship between velocity, displacement, and acceleration can be shown in the following equations:

$$for(j = 0; j \le n-1; j++); \qquad (6)$$

$$\{W_j = r*(j+1); T_i = [h(W_j)*m_j]^c \bmod N\}; \qquad (7)$$

$$Output(T_0, T_2, \ldots T_{n-1}); \qquad (8)$$

As both the knowledge of engineering problems and the theory research develops a lot of new excavation problems have turned up. The local fractional integral of $f(x)$ can be totally defined as the following Eq.9.

$$ {}_aI_b^{(\alpha)} f(t) = \frac{1}{\Gamma(1+\alpha)} \int_a^b f(t)(dt)^\alpha = \frac{1}{\Gamma(1+\alpha)} \lim_{\Delta t \to 0} \sum_{j=0}^{j=N-1} f(t_j)(\Delta t_j)^\alpha \qquad (9)$$

Its local fractional Hilbert transform, denoted by $f_x^{H,\alpha}(x)$ is defined by

$$H_\alpha\{f(t)\} = \hat{f}_H^\alpha(x) = \frac{1}{\Gamma(1+\alpha)} \int_R \frac{f(t)}{(t-x)^\alpha}(dt)^\alpha \qquad (10)$$

Where x is real and the integral is treated as a Canchy principal value, that is,

$$\frac{1}{\Gamma(1+\alpha)} \int_R \frac{f(t)}{(t-x)^\alpha}(dt)^\alpha = \lim_{\varepsilon \to 0}\left[\frac{1}{\Gamma(1+\alpha)} \int_{-\infty}^{x-\varepsilon} \frac{f(t)}{(t-x)^\alpha}(dt)^\alpha + \frac{1}{\Gamma(1+\alpha)} \int_{x+\varepsilon}^{\infty} \frac{f(t)}{(t-x)^\alpha}(dt)^\alpha\right] \qquad (11)$$

To obtain the inverse local fractional Hilbert transform, write again Eq. (12) as

$$\hat{f}_H^{\alpha}(x) = \frac{1}{\Gamma(1+\alpha)} \int_{-\infty}^{\infty} \frac{f(t)}{(t-x)^{\alpha}} (dt)^{\alpha}$$
$$= \frac{1}{\Gamma(1+\alpha)} \int_{-\infty}^{\infty} f(t) g(x-t)(dt)^{\alpha} \quad (12)$$
$$= f(x) * g(x),$$

According to the effect of external load, there are three different types of stresses can be identified. These stresses are related to the nature of the deforming force applied on the body. The first type was known as tensile stresses, the second type was known as compressive stress, and the third type was known shear stress. The shear stress takes place from the force vector component parallel to the cross section. Shear stress can be obtained and the equation of motion is in the follows forms:

$$\partial_j (C_{ijkl} \partial_k u_l + e_{kij} \partial_k \varphi) - \rho \ddot{u}_i = 0 \quad (13)$$

Under the linear theory, that is:

$$\partial_j (e_{ijkl} \partial_k u_l - \eta_{kij} \partial_k \varphi) = 0 \quad (14)$$

In general, frequency is the number of occurrences of repeating events per unit time and the period is the duration of one cycle in repeating event. Angular frequency can be defined as the rate of change of angular displacement (θ) during rotation. The dynamic responses include natural frequency, vibration frequency (forced frequency), damping factor, dynamic acceleration, dynamic displacement, dynamic velocity, and impact factor. The natural frequency depends on the geometry of the structure, materials properties, loads effect, extent and pattern of cracks, and effect of post-tensioning. In elastic state, the stiffness of structure in good state and the natural frequency is not equal to the zero. In plastic state, the natural frequency is equal to zero and the structure has not enough stiffness and the return period of structure would be infinity which mean if the structure subjects to a disturbance, the structure will never return to its original equilibrium state. Some experimental works shown that the natural frequency increases with the increasing of pre-stressing force (tension), but it decreased when the tension force arrive to the cracking point. The appearance of cracks has significant effect not just on the deflection and redistribution of the internal forces, but also has effect on the dynamic responses such as natural frequency and damping. Progressive cracks cause to decrease the natural frequency (even by 50%) and increasing the damping properties.

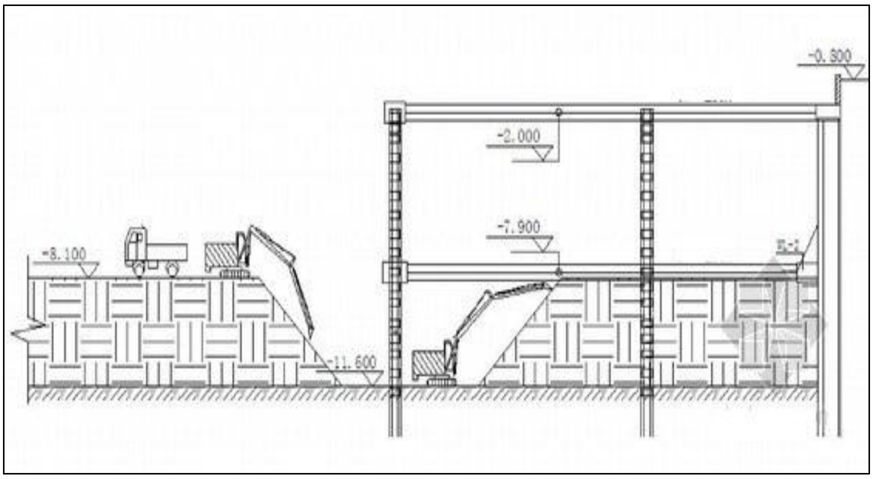

***Figure 3**: The structure diagram for the supporting structure of a deep foundation pit*

4. The experiment study and data analysis

Damage inspection, static and dynamic load tests are adopted for the deep foundation pits structures after repairing and strengthening. The results of damage inspection of the deep foundation pits structural parts show that the state of structural members is good. It can be noted that the maximum tensile stress is equal to 2.3MPa which takes place in the top left of box girders No.4 and No.20 at distance 1.78m and 7.35m respectively. There is not tensile stress or compressive stress in the bottom of box girders. For bottom of box girder, the maximum compressive stress is equal to -2.3MPa within bottom right of box girders No.3 and No.21 at distance 14.9m and 76.5m respectively. There is not tensile stress or compressive stress in the top of box girders. The external pre-stressing systems of the strengthening deep foundation pits are in good state. The state of the deep foundation pits decks system is in good state but there are some places have cracks and bleeding of asphalt on deep foundation pit.

The traditional fixed value analysis method has not considered the randomness of these parameters and therefore the results of this method will have some uncertainty. Reliability-based analysis method can consider the randomness of these parameters and the correlation between them fully. As a result, to search for an optimization algorithm is the key. Therefore, the Pk is equal to 360kN. Support scheme of pile anchor in deep foundation pit based on the application of universality in the design and calculation of uncertainty, it is necessary to analysis and research this kind of support scheme. This type can be reduced the structure life. The experiment results are shown in the figure 4-6 in the following.

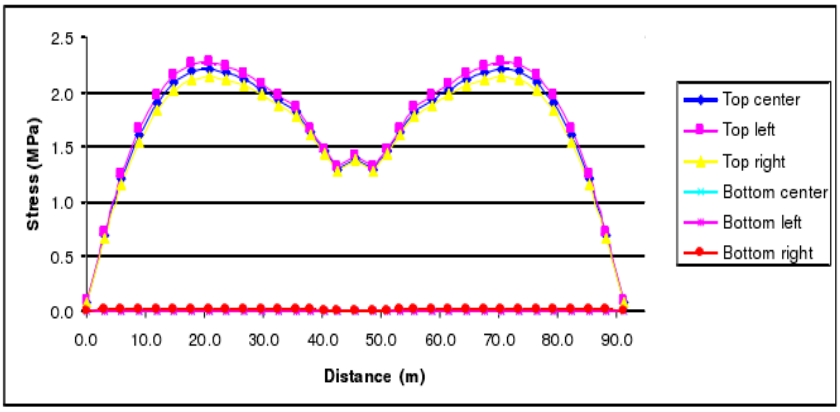

***Figure 4**: The structure simulation result for stress*

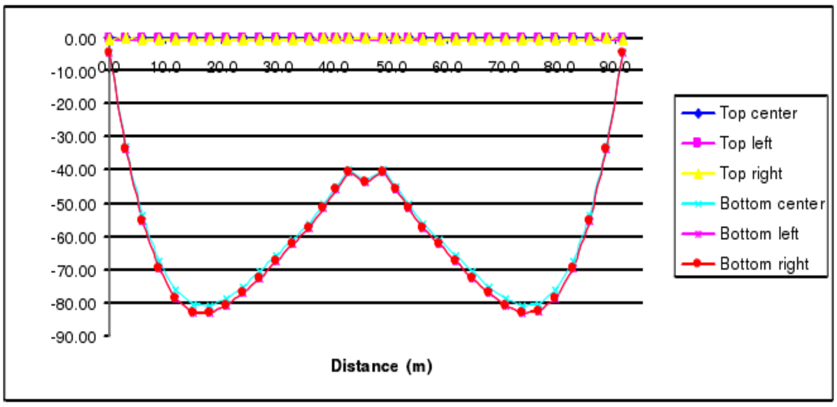

***Figure 5**: The structure simulation result for press*

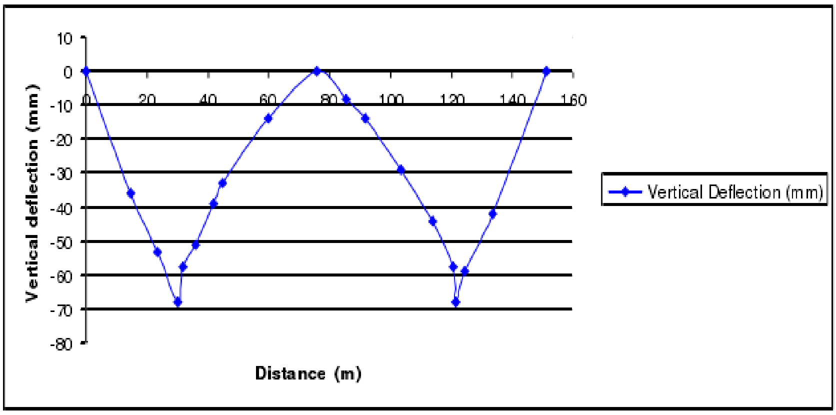

***Figure 6**: The structure simulation result for vertical deflection*

The first type is surface damage which has surface scrapes and small nicks; this type does not need to repair. The second type is minor damage which has isolated cracks, nicks, and spalls and this type needs to repair. The third type is moderate damage which consists of concrete cracks and wide spalls exposing reinforcing steel and pressurising strand. This type can be reduced the structure life. The fourth type is severe damage which includes exposed and damaged pre-stressing tendons and reinforcing steel along with loss of important cross section. From Figure 4-6 it can be noted that the higher value of maximum bending moment (positive) is equal to 3266.3kN/m which locates in the centre of the deep foundation pit at distance 140m and the higher value of minimum bending moment (negative) is equal to -9612.8kN.m which takes place in the pier box girder (pier No.3) at distance 18.5m. The maximum positive vertical shear force occurs in the pier box girder (pier No.3) at distance 18.5m which equal to 615.7kN and the maximum negative vertical shear force occur in pier box girder (pier No.2) at distance 9.5m which is equal to -599.4kN. For axial forces, the maximum positive and negative values are equal to 267kN and -447.9kN respectively, which occur along the length of middle span of the deep foundation pit. The results of static load tests of the deep foundation pits structure show that the tested values of static structural response are less than the theoretical values, indicating that the structural strength of the deep foundation pit structure meets the design requirements and the state of elastic working state is good, but deep foundation pit has just dynamic load test. The results of dynamic load tests analysis after repairing and strengthening processes of deep foundation pits structures show that the values of measured natural frequencies are increased and vibration frequencies are decreased. Therefore, the repairing and strengthening methods are effective to improve the static and dynamic structural performance of deep foundation pits structure.

5. Conclusions

Static and dynamic load tests results are used to evaluate the structural performance of the deep foundation pits structure by comparing with theoretical analysis. In order to reduce the supporting failure rate and to improve the performance of damage inspecting of supporting structure in deep foundation pit construction, the structure analysis based fractional algorithm and damage inspecting system is proposed in this paper. The results of static load test of the deep foundation pits structure show that deep foundation pit gives the maximum value of negative and positive bending moment, and vertical deflection, from others two deep foundation pits, which are -60621kN.m, 29180.5kN.m, and 40.10mm respectively. The deep foundation pit gives the maximum value of concrete strain which is 645.5. The dynamic load test results show that the deep foundation pit gives the maximum value of natural frequency and vibration frequency which are equal to 4.40Hz and 5Hz respectively, Jiamusi deep foundation pit gives the maximum value of dynamic displacement which is equal to 7.56mm, and the deep foundation pit gives the maximum value of impact factor which is 1.15. According to evaluation process, the deep foundation pits the maximum value of load test coefficient which is equal to 2.49. This value is more than the allowable coefficient of load test (1.0). Also the evaluation results show that the deep foundation pits structure need to repair and strengthen because the elastic working state and stiffness of the deep foundation pits structure don’t meet the design requirements.

References

[1] Zhou, Hong Bo, and H. Zhang. "Risk Assessment Methodology for a Deep Foundation Pit Construction Project in Shanghai, China." Journal of Construction Engineering & Management 137.12(2011):1185-1194.

[2] Wang, Haibiao, et al. "Safety Monitoring and Early Warning for Deep Foundation Pit Construction." Tenth International Conference of Chinese Transportation Professionals 2015:3493-3500.

[3] Wang, Haibiao, et al. Safety Monitoring and Early Warning for Deep Foundation Pit Construction. 2010.

[4] Feng, Yong, and K. B. Shi. "Optimum Decision-Making of Deep Foundation Pit Construction Project Based on the Least Variance Priority Method." Building Science (2009).

[5] Dai, Bin, W. D. Wang, and X. U. Zhong-Hua. "Design & Practice of Deep Foundation Pit Constructed by Top-down Method in Dense-constructed Area." Underground Space (2005).

[6] Liu, Chun Yuan, W. W. Cao, and Y. Liu. "Simulation Analysis on Deep Foundation Pit Construction Near the History Style Construction." Advanced Materials Research 671-674.671-674(2013):113-116.

[7] Ye, Junneng Liu Ganbin. "Forewarning Index for Deep Foundation Pit Construction and Risk Assessment in Ningbo area." Chinese Journal of Underground Space & Engineering (2012).

[8] Zhu, Fengjun. "On strategic analysis of deep foundation pit construction's influence on surrounding subway tunnels." Shanxi Architecture (2015).

[9] Li, Hongqing, and G. M. Corporation. "Analyses the effect of a subway station deep foundation pit construction on surrounding buildings and protective measures." Shanxi Architecture (2015).

[10] Luo, Yimin. "Thinking about the Construction of Deep Foundation Pit Construction Supporting Technology Points." Science & Technology & Innovation (2015).

[11] Hui, L. "Existing building stability evaluation by deep foundation pit construction of subway station." (2015).

[12] Yang, Zhan. "The Subway Engineering Rock Blasting Test of Deep Foundation Pit Construction Technology." Guangdong Architecture Civil Engineering (2015).

[13] Dou, Qiang. "Application of controlled blasting technology in deep foundation pit construction." Journal of Changjiang Institute of Technology (2016).

[14] Lee C, Kim J H, Lee C, et al. “Optimized Brightness Compensation and Contrast Enhancement for Transmissive Liquid Crystal Displays”. IEEE Transactions on Circuits & Systems for Video Technology, 2014, 24(4):576-590.