土地整理中大面积土方工程几种最优计划高的计算方法

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摘 要: 在土地整理工程中涉及到大面积土方工程, 在不同条件下, 有着不同的计划高。该文在保加利亚留保米尔教授[1]关于不受任何条件限制下的最优计划高计算的理论基础上, 提出了5种不同的特定条件下最优计划高的理论计算方法。采用这些计算方法计算计划高, 在原定条件下, 土方量将是最小的, 而且计算也较简便。

关键词: 土方工程; 最优计划高; 最小二乘方原理
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计划高是土方工程施工中的计划线或计划面。在线性土方施工中, 如铁路、道路、沟管、水渠、隧道等, 计划高就是设计线; 在大面积土方施工中, 用机械实施的农田平整, 村、寨、集镇规划建设及飞机场、大型工业基地等, 计划面便是设计面。在特定地形中, 关系到土方量的主导因素便是计划高。计划高定得正确与否, 对土方工程施工成本、施工工期及场地平整后对基本建设的适用性, 有着很大关系和深远的影响。

1 大面积土方工程计划高的计算公式

在大面积土方工程中, 关于计划高的计算, 目前采用下列一些公式。

四方棱柱体计算法中, 计划高(H_0)的计算[2~5]

$$H_0 = \frac{1\sum H_1 + 2\sum H_2 + 4\sum H_4}{4N} \pm \frac{Q}{Na^2} \pm \Delta H_0 \quad (1)$$

在三角棱柱体算法中, 计划高(H_0) 的计算[2~5]

$$H_0 = \frac{\sum H_1 + 2\sum H_2 + 3\sum H_3 + 6\sum H_6}{6N} \pm \frac{Q}{Na^2} \pm \Delta H_0 \quad (2)$$

式中 H_0—— 计划高; H_1、H_2、H_3、H_4、H_6—— 表示一、二、三、四、六个四方形或三角形共有顶点的自然地面标高; N —— 方格数; a—— 每个方格的边长; Q —— 借土量或弃土量, 借土取正号, 弃土取负号; ΔH_0—— 考虑土壤可松性而引起的修正标高。

修正标高可用下式[2,4] 计算

$$\Delta H_0 = \pm \frac{V_B h'_p \pm V_T(1 + h'_p)}{F_H + F_B(1 + h'_p)}$$

式中 V_T—— 自然状态下盈亏的土方量, m^3; V_B—— 全部挖方量, m^3; F_H—— 挖方面积, m^2; F_B—— 填方面积, m^2; h'_p—— 最后体积增加百分数。

(1)、(2) 式右边的第一项是根据土方量平衡(即土方施工中, 使土方量恰好等于填土量) 原则推导出来的。其余两项, 是根据土方需借、弃土及考虑土壤的可松性附加进去的。根据上两式计算的计划高, 其土方量不一定最小。另外, 根据根据这两式得出的计划面, 只能是一个水平面(或者作一定的单向倾斜), 不能作任意倾斜。为了解决上述问题, 采用最小二乘方原理研究另一种计算方法。

2 最优设计平面的选择

2 1 最优设计平面的一般表达式

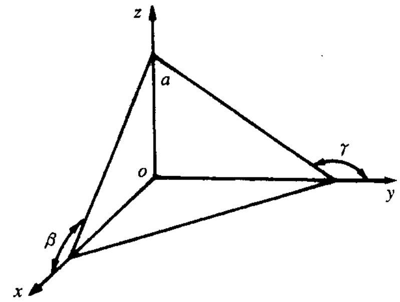

图1 计划面为任意平面的位置图

Fig. 1 Position of an arbitrary plane as a planned plane

如图1所示, 设计划面为任意一个平面, 其方程为

$$z = a + bx + cy \quad (3)$$

式中 $b = \tan\beta$ $c = \tan\gamma$

设自然地面上各点: $1(x_1, y_1, z_1)$, $2(x_2, y_2, z_2)$, …, $n(x_n, y_n, z_n)$ (图中未标出), 则在任意平面上, 相应于1, 2, …, n 各点之垂直投影点为:

$$z'_1 = a + bx_1 + cy_1,$$
$$z'_2 = a + bx_2 + cy_2,$$
$$\cdots,$$
$$z'_n = a + bx_n + cy_n$$

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自然地面上各点与任意平面上相应各点之误差为

$$\begin{cases} v_1 = z_1' - z_1 = a + bx_1 + cy_1 - z_1 \\ v_2 = z_2' - z_2 = a + bx_2 + cy_2 - z_2 \\ \cdots \\ v_n = z_n' - z_n = a + bx_n + cy_n - z_n \end{cases} \tag{4}$$

$$\sum v_n = (a + bx_1 + cy_1 - z_1)^2 + (a + bx_2 + cy_2 - z_2)^2 + \cdots + (a + bx_n + cy_n - z_n)^2$$

欲求最优平面, 必须 $\sum v_n$ 为最小, 即

$$\begin{cases} \dfrac{\partial \sum v^2}{\partial a} = 0, 得\ na + b\sum x + c\sum y - \sum z = 0 \\ \dfrac{\partial \sum v^2}{\partial b} = 0, 得\ a\sum x + b\sum x^2 + c\sum xy - \sum xz = 0 \\ \dfrac{\partial \sum v^2}{\partial c} = 0, 得\ a\sum y + b\sum yx + c\sum y^2 - \sum yz = 0 \end{cases} \tag{5}$$

式中 $\sum x, \sum y, \sum z$ —— 表示 $\sum_{i=1}^{n} x, \sum_{i=1}^{n} y, \sum_{i=1}^{n} z$, 以下同。

解(5) 式得

$$\begin{cases} a = \dfrac{A\sum x^2 + B\sum x + D\sum xy}{E\sum y^2 + F\sum xy + G\sum y} \\ b = -\dfrac{A\sum x + Bn + D\sum y}{E\sum y^2 + F\sum xy + G\sum y} \\ c = \dfrac{E\sum yz + F\sum xz + G\sum z}{E\sum y^2 + F\sum xy + G\sum y} \end{cases} \tag{6}$$

式中 $A = \sum y^2\sum z - \sum yz\sum y$; $B = \sum xy\sum yz - \sum xz\sum y^2$; $D = \sum xz\sum y - \sum xy\sum z$; $E = n\sum x^2 - (\sum x)^2$; $F = \sum x\sum y - n\sum xy$; $G = \sum x\sum xy - \sum x^2\sum y$。

将 a、b、c 代入方程(3) 中, 即为最优设计平面。这是一般的情形, 下面研究几种特殊情况。

2 2 5 种特定情况最优计划高的计算

2 2 1 场地为正方形且方格各点间距相等

如图 2 所示, 设 n 代表总点数($n = 25$)

$$y = 0, d, 2d, \Lambda, (\sqrt{n} - 1)d$$

$$x = 0, d, 2d, \Lambda, (\sqrt{n} - 1)d$$

$$z = z_0, z_1, z_2, \Lambda, (\sqrt{n} - 1)d$$

式中 n —— 各地段内点数; $\sqrt{n} - 1$ —— 横坐标或纵坐标上正方形边数, 则有

$$\begin{cases} \sum x = \sum y = [d + 2d + \Lambda + (\sqrt{n} - 1)d]\sqrt{n} \\ \quad = \dfrac{n}{2}(\sqrt{n} - 1)d \\ \sum x^2 = \sum y^2 = \sqrt{n}[d^2 + 2^2d^2 + \Lambda + (\sqrt{n} - 1)^2 d^2] \\ \quad = \dfrac{n(\sqrt{n} - 1)(2\sqrt{n} - 1)d^2}{6} \\ \sum xy = [d + 2d + \Lambda + (\sqrt{n} - 1)d]^2 \\ \quad = \left[\dfrac{(\sqrt{n} - 1)\sqrt{n}}{2}\right]^2 d^2 \end{cases} \tag{7}$$

将(7) 代入(6) 式中, 可得 a、b、c。

设求得: $a = a_1, b = b_1, c = c_1$

则计划平面为

$$z = a_1 + b_1x + c_1y$$

各点施工填挖量为

$$\begin{cases} v_1 = z_1' - z_1 = a_1 + b_1x_1 + c_1y_1 - z_1 \\ v_2 = z_2' - z_2 = a_1 + b_1x_2 + c_1y_2 - z_2 \\ \cdots \\ v_n = z_n' - z_n = a_1 + b_1x_n + c_1y_n - z_n \end{cases} \tag{8}$$

式中正号代表填方, 负号代表挖方。

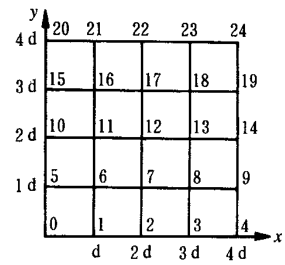

图 2 正方形网格计算图

Fig 2 Calculated figure of square net

2 2 2 计划面必须保持某已知点(P) 的高程(h)

设 P 为特定已知点, 计划面必须维持在此点不被变动。

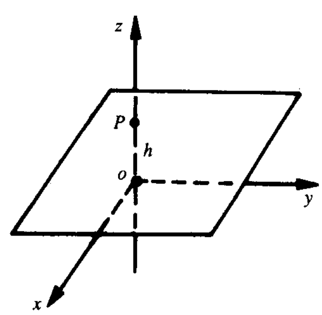

图 3 计划面过已知点 P 的图

Fig 3 Planned plane passing through a given point P

坐标取法如图 3 所示: 选 P 在某水平面的投影作为坐标原点, 并使 $OP = h$(已知高程)。

将图 3 与图 1 比较, $OP = h = a$, 因 $a = h$, 故方程(3) 式第一式不起作用, 也不能采用。由方程(5) 第一、第三式可求 b、c 之值, 即

$$\begin{cases} b\sum x^2 + c\sum xy = \sum xz - h\sum x \\ b\sum yx + c\sum y^2 = \sum yz - h\sum y \end{cases} \tag{9}$$

及 $a = h$

解方程, 得

$$\begin{cases} b = \dfrac{B\sum xy - c\sum y^2}{\sum xy\sum yx - \sum x^2\sum y^2} \\ c = \dfrac{A\sum yx - B\sum x^2}{\sum xy\sum yx - \sum x^2\sum y^2} \end{cases} \tag{10}$$

及 $a = h$

式中 $A = \sum xz - h\sum x$; $B = \sum yz - h\sum y$。

(10) 式便是计划面必须维持某一点高程时, 关于 $z = a + bx + cy$ 中的 a、b、c 的解。

2 2 3　计划面必须保持某个方向的倾角

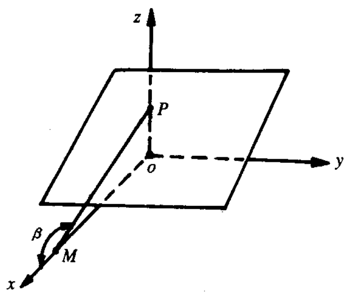

图 4　计划面与 X 轴保持某一角度

Fig. 4　Planned plane retaining an angle degree with x axis

如图 4 所示, 设 PM 之倾斜为要求保持某一方向的倾角, 作 x 轴标在 PM 垂直投影面之内, 使 PMO 在同一垂直平面内。可得 $b = \tan\beta =$ 恒量。因此, 方程式(5) 第二式不能采用, 得下列方程组

$$\begin{cases} na + c\sum y = \sum z - b\sum x \\ a\sum y + c\sum y^2 = \sum yz - b\sum yx \end{cases} \tag{11}$$

及　$b = \tan\beta$

解方程, 得

$$\begin{cases} a = \dfrac{B\sum y - A\sum y^2}{D} \\ c = \dfrac{A\sum y - Bn}{D} \\ b = \tan\beta \end{cases} \tag{12}$$

式中　$A = \sum z - B\sum x$; $B = \sum yz - b\sum yx$;
$D = (\sum y)^2 - n\sum y^2$。

2 2 4 计划面必须保持某两点 P_1、P_2 高程 h_1、h_2

选择坐标如图 5 所示, 图中 z 轴通过 P_1 点; $a = h_1$(恒量); P_1P_2 与 y 轴在同一垂直平面内。

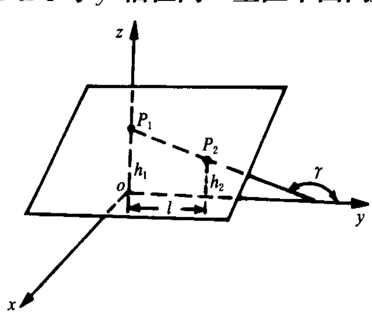

图 5　计划面过两已知点的图

Fig. 5　Planned plane passing through two given points P_1 and P_2

则　$c = \tan\gamma$

$$\tan(180° - \gamma) = \frac{h_1 - h_2}{l}$$

即　$\tan\gamma = \dfrac{h_1 - h_2}{l}$

故　$c = \dfrac{h_1 - h_2}{l}$　$(h_1 > h_2)$

因 a 与 c 都是恒量, 故方程(5) 式中第三式不能采用。在这种情况下, 可得下列方程组

$$\begin{cases} a = h_1 \\ b = \dfrac{\sum xz - a\sum x - c\sum xy}{\sum x^2} \\ c = \dfrac{h_1 - h_2}{l} \quad (h_1 > h_2) \end{cases} \tag{13}$$

2 2 5　计划面必须保持水平

如图 6 所示, $\gamma = 180°$, $\beta = 180°$, 而 $b = \tan\beta = \tan 180° = 0$; $c = \tan\gamma = \tan 180° = 0$。

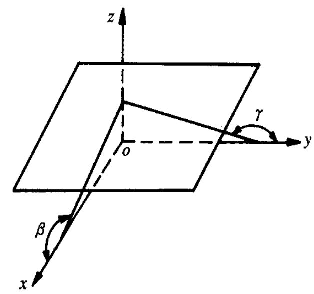

图 6　计划面保持水平面的图形

Fig. 6　Planned plane retaining horizontal direction

因此, 在式(5) 中, 第二、三式也不能采用, 只有第一式可以采用, 得

$$na + b\sum x + c\sum y - \sum z = 0$$

即 $z = a = \dfrac{\sum z}{n}$　(因 $b = c = 0$)　(14)

(14) 式的意义在于计划面必须保持水平时, 它的计划高(H_0) 为各方格顶点自然地面标高之平均值(即算术平均自然地面标高值)。

如果采用加权平均, 令 $H = z$, 在四方棱柱方法中则得

$$z = \frac{\sum z_1 + 2\sum z_2 + 4\sum z_4}{4N} \tag{15}$$

同理, 在三角棱柱方法中可得

$$z = \frac{\sum z_1 + 2\sum z_2 + 3\sum z_3 + 6\sum z_6}{6N} \tag{16}$$

将(1) 式及(2) 式与(15) 式及(16) 式比较, 除附加项以外, 完全一样。可见, 后者是前者的特殊情况。

3　计算实例

确定图 2 及表 1 所列数据的最优计划面。

根据式(7), 得

$$\sum x^2 = \sum y^2 = \frac{n(\sqrt{n} - 1)(2\sqrt{n} - 1)d^2}{6}$$

$$= \frac{25(\sqrt{25} - 1)(2\sqrt{25} - 1)\times 10^2}{6} = 15000$$

表 1 某场地自然标高观测结果表

Table 1 Observed results of natural elevation in a squre site

点号	y/m	x/m	z/m	点号	y/m	x/m	z/m
0	0	0	16.541	13	20	30	8.973
1	0	10	10.350	14	20	40	9.563
2	0	20	8.540	15	30	0	6.011
3	0	30	6.320	16	30	10	8.453
4	0	40	4.053	17	30	20	8.632
5	10	0	10.437	18	30	30	8.710
6	10	10	9.563	19	30	40	10.070
7	10	20	8.973	20	40	0	5.461
8	10	30	8.460	21	40	10	7.032
9	10	40	7.304	22	40	20	10.415
10	20	0	8.312	23	40	30	14.560
11	20	10	7.456	24	40	40	17.053
12	20	0	8.095	n= 25	$\sum y=500$	$\sum x=500$	$\sum z=229.287$

$$\sum xy = \left[\frac{(\sqrt{n}-1)\sqrt{n}}{2}\right]^2 \times 10^2 = 10000$$

同理, 得

$$\sum xz = 4653.03 \quad \sum yz = 4731.47$$

将此值代入方程(5) 中, 得

$$25a + 500b + 500c - 229.287 = 0$$

$$500a + 15000b + 10000c - 4653.03 = 0$$

$$500a + 10000b + 15000c - 4731.47 = 0$$

解之

$$a = +8.3194, \quad b = +0.013458, \quad c = +0.029146$$

根据 $z_1 = a + bx_1 + cy_1$

$$v = z_1 - z$$

得填挖高:

$v_0 = -0.8222$ $v_1 = -1.896$ $v_2 = +0.049$

$v_3 = +0.403$ $v_4 = +4.805$ $v_5 = -1.826$

$v_6 = -0.818$ $v_7 = -0.093$ $v_8 = +0.555$

$v_9 = +1.845$ $v_{10} = +0.590$ $v_{11} = +1.581$

$v_{12} = +1.126$ $v_{13} = +0.333$ $v_{14} = -0.122$

$v_{15} = +3.183$ $v_{16} = +0.875$ $v_{17} = +0.831$

$v_{18} = +0.888$ $v_{19} = -0.338$ $v_{20} = +4.024$

$v_{21} = +2.588$ $v_{22} = -0.661$ $v_{23} = -4.671$

$v_{24} = -7.029$

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Calculation Method of the Optimum Planned-Elevation for Bulk Wide-Area Earthwork in land Consolidation ········· (173)

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Abstract: In different conditions, there are different planned-elevations for the bulk wide-area earthwork. On the basis of theory presented by professor Leiboumils (Bulgarian), with respect to calculation of the optimum planned-elevation which is not subject to any condition, five theorical formulae for calculating the optimum planned-elevation in different special conditions are suggested: first, the distance of each point is equal in the ground of square; second, the planned area without retaining a height of given point (P); third, the planned area must retain a inclined angle in one direction; fourth, the planned area must retain the height h_1 and h_2 for two given points; fifth, the planned area must retain horizontal. In this way, the volume of earthwork can be the least and the calculation can also be simpler if calculation is made in accordance with the formulae under the original condition.

Key words: earthwork; optimum planned-elevation; least square principle

· Review and Forum ·

Relationship Between Increasing Grain Output and Utilization Patential of Agricultural Water Resources in Severe-arid Northwestern Ecological Zones ········· (177)

Ju Zhengshan[1], Zhang Fengrong[2], Liu Xiaoxia[3] (1. *Center for Land Consolidation and Rehabilitation, Ministry of Land and Resources, Beijing* 100035, *China*; 2. *China Agricultural University, Beijing* 100083, *China*; 3. *Xixia Costume Ltd. Co. Shandong Province, Xixia* 265300, *China*)

Abstract: Based on the study of status quo of agricultural water resources utilization in Northwestern Ecological Zones, this paper analyzed the water utilization potential and increasing production potential at the theoretical level by the method of AEZ. The results are: the whole Northwestern Ecological Zone is suffered from the shortage of water resources; Its current water use efficiency is low and the waste is as serious as shortage; Water is key to exert the biomass and maximum potential yield of crops. If the water use efficiency rises up 10%～20%, the land production potential will be surmounted greatly.

Key words: northwestern ecological zone; water use efficiency; potential analysis

Commercialized Operation Model and Development of Integrated Energy-Environment Engineering on Scaled Livestock Farms ········· (181)

Yao Xiangjun[1], Hao Xianrong[2], Guo Xianzhang[1] (1. *Energy & Environmental Protection Institute, Chinese Academy of Agricultural Engineering, Beijing* 100026, *China*; 2. *Rural Renewable Energy Office, Department of Science, Technology and Education, Ministry of Agriculture, Beijing* 100026, *China*)

Abstract: This paper defines the concept of energy (biogas)-environmental protection engineering on scaled livestock farms, which differs from large/medium scale biogas plants widely developed in China at previous time. Driven by pressure from environmental sector and demand for non-polluted agricultural products, it stresses that the integration of waste treatment with its utilization and the integration of livestock & poultry breeding with planting. The paper states that anaerobic digestion as the key technology in the system is significant for effluent control of livestock farms. Barriers to widely extend this technology are analyzed in its commercial development. Finally a case of feasibility study on swine farms in Luoniushan District of Hainan Province is presented.

Key words: livestock farm; enengy-environmental protection engineering; commercialized operation

Research Advances of Postharvest Physiology, Postharvest Pathology and Storage and Transport Technologies for Longan Fruits ········· (185)

Lin Hetong[1,2], Xi Yufang[1], Chen Shaojun[2], Chen Jinquan[2], Hong Qizheng[2] (1. *Department of Food Science and Nutrition, Zhejiang University, Hangzhou* 310029, *China*; 2. *College of Food Science, Fujian Agriculture and Forestry University, Fuzhou* 350002, *China*)

Abstract: The advances in the studies of postharvest physiology, postharvest pathology, differing storage and transport characteristics of cultivars, storage and transport technologies for longan fruits under