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Original article

UAV Utilization for Efficient Estimation of Earthwork Volume Based on DEM

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Abstract

In the era of the 4th industrial revolution, smart construction, in which new technologies such as UAV (Unmanned Aerial Vehicle) are fused, is attracting attention in the construction field. However, the method of estimating earthwork volume using DEM generated by UAV survey according to practical regulations such as construction design guidelines or standard product counting is not officially recognized and needs to be improved. In this study, different types of UAV were measured and DEM was obtained using this data. The DEM (Digital Elevation Model) thus obtained was analyzed for changes in the amount of earthworks according to the size of the GSD (Ground Sample Distance). In addition, the amount of earthwork by DEM and the amount of earthwork by existing design drawings were compared and analyzed. As a result of the study, it was suggested that images with a GSD of 5cm or less are effective to generate a high-quality DEM. Next, as a result of comparing the earthwork volume calculation method using DEM and the earthwork volume based on the existing 2D design drawings, a difference of about 1% was shown. In addition, when the design earthwork amount calculated by the double-section averaging method was compared with the designed earthwork amount using DEM data by UAV survey, a difference of about 1% was found. Therefore, it is suggested that the method of calculating the amount of earthworks using UAV is an efficient method that can replace the existing method.

Keywords : Unmanned Aerial Vehicle Survey, Digital Elevation Model, Ground Sample Distance, Earthwork Volume Estimation

1. Introduction

In the era of the 4th industrial revolution, construction technology is also in the flow of many changes. The traditional construction techniques of design, construction and maintenance are becoming more efficient. Unlike the past, recent construction works tend to be very complex in design and construction as the number of large and irregularly shaped structures increases. Therefore, when designing in 2D, there is a high possibility of design errors such as mismatching of positions between detailed structures in the process of creating detailed drawings of structures in multiple sheets (Cho, 2020). In addition, it takes a lot of time to understand the overall shape of the structure by analyzing several floor plans, and there is a possibility of calculation errors because the quantity calculation is also done manually. In particular, when constructing complex structures, it is impossible to accurately identify construction errors with 2D

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drawings, and there is a risk that construction quality may deteriorate due to re-construction or construction delays (Korea Expressway Corporation, 2016). However, unlike the existing 2D drawings, designing as a 3D model enables intuitive analysis of the shape of the structure above all else.

To this end, if UAV or LiDAR (Light Detection And Ranging) is used, the current progress or situation can be grasped by directly superimposing the modeling data of the target structure on the 3D design model during construction. In general, the existing topographic survey for construction design is performed using aerial photogrammetry and aerial LiDAR surveying methods for large-scale construction, but for small-scale construction, ground surveying methods using GNSS (Global Navigation Satellite System) and total stations are used. Conduct. Although aerial photogrammetry and aerial LiDAR surveying have excellent accuracy, the resolution of photos and laser point density are inferior to those of UAV. Therefore, it has disadvantages such as low accuracy and high cost to use as 3D terrain modeling data. The ground survey method using GNSS and total station also takes an excessive amount of time and money because it surveys the entire terrain on foot and observes the terrain undulations point by point. Moreover, since it is difficult to observe a point that cannot be approached on foot, the density of the station greatly drops, and the location of the observation point changes according to the subjective judgment of the operator, so it is difficult to accurately represent the topography (Cho, 2020).

If a DEM is created through UAV surveying and the amount of earthworks is calculated based on this, the time required for inspection is reduced, and ready-made management or process management can be performed efficiently. However, at present, it is very difficult to apply this method. This is because it is stipulated that the amount of earthworks should be calculated using the double-sided average method according to the design guidelines for construction works or standard product counting (Ulsan Metropolitan City, 2021). Since the amount of earthwork is an important factor directly related to the construction amount, the burden on the client is high to arbitrarily apply the amount of earthwork calculated by any method other than the prescribed one. The design guidelines for construction work stipulate the detailed standards necessary to carry out the design, and the standard product calculation is used to prepare the estimated price of the construction work, so most of the design details are prepared based on these regulations (Cho *et al*., 2020).

In this study, DEM and orthographic images are produced by observing each type of UAV in order to identify these problems and find an advanced method. In addition, the efficiency of the DEM method is presented by comparing the DEM-based method of estimating earthworks and the existing estimating methods.

2. Method

There is a method using TIN (Triangulated Irregular Network) and DEM as a method of calculating earthwork volume by processing point cloud data, the result of UAV survey. Since these two methods use the same point cloud only with different data formats, the accuracy of the calculated earthwork volume is almost the same.

2.1 Estimation of earthwork volume by DEM grid

Point clouds generated by UAV surveys have non-uniform point spacing. Therefore, in order to generate an orthogonal image, the point cloud needs to be converted into a DEM in the form of a grid with regular intervals. DEM is an intermediate result generated in the process of producing an orthographic image, which is converted into a lattice form by interpolating and rearranging point cloud data. Since the DEM grid generated by the UAV survey is created with the same size as the GSD of the captured image, if the GSD size is known, the area of each grid can be known. In addition, since the DEM grid has a three-dimensional coordinate value, if the height is applied to the area of each grid, each grid is expressed in the form of a square column, so the volume can be calculated.

Estimation of earthwork volume by DEM is shown in Fig. 1, the volume of each lattice constituting the DEM is calculated one by one, and then the total volume is obtained by summing them all up (Pix4D, 2021). This method is widely used in most image processing programs because it is easier and faster to calculate than the method using TIN. However, depending on the program, Pix4D calculates earthwork volume based on DSM (Digital Surface Model), whereas Metashape is designed to use both DSM and DEM.

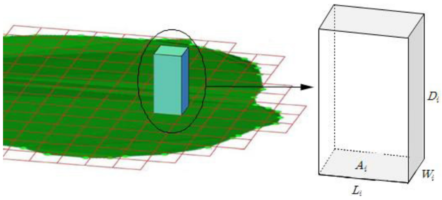


Fig. 1. Square pillar forming DEM

The volume of each grid is expressed as Eq. (1) by multiplying the area of the grid by the height.

$$V_i = A_i \times D_i = L_i \times W_i \times D_i \tag{1}$$

where A_i is the grid cross-sectional area, L_i is the length of the grid, W_i is the width of the grid, and D_i is the height of the grid. At this time, the length (L_i) and width (W_i) of the grid are the same as GSD.

2.2 UAV survey for DEM acquisition

An area of about 250,000㎡ was selected as the site for the construction of an urban high-tech industrial complex in Namdong-gu, Incheon, as the test subject. Construction started in December 2019, but the time to conduct the experiment was just before the earthwork started, so it was easy to conduct various experiments, so it was selected as a study area. Fig. 2 is an image showing the study area (Naver map, 2021).

Fig. 2. Study area

2.2.1 UAV applied to the experiment

Two types of vertical take-off and landing fixed-wing UAV and rotary-wing UAV were used in this study.

The vertical take-off and landing fixed-wing UAV is a FireFly6 Pro model manufactured by BirdsEyeView Aerobotic in the United States. To reduce battery consumption, the rotorcraft takes off up to an altitude of 50m, and after that, the propeller tilts in the direction of the aircraft to fly at high speed in the fixed-wing method. This UAV can be equipped with various sensors such as multi-spectral cameras and video cameras, and can fly for 50 minutes with two batteries. In particular, RGB cameras, which are mainly used for UAV surveying, can be equipped with high-resolution cameras of 36 and 42 megapixels in addition to 24 megapixels, so high-resolution images can be acquired even at high altitudes. In addition, RTK (Real Time Kinematic)-GNSS is mounted, vibration is low and flight altitude is constant, so it is possible to obtain high-accuracy images compared to other models.

The rotorcraft UAV is China DJI's Inspire II. Originally, this model was developed to be used for video shooting, but it can also be equipped with an RGB camera, so it can be partially used for surveying. The maximum flight time is about 27 minutes, and it is intended for shooting in a narrow area rather than a large area. Since this model also flies automatically, it is easy to operate and the flight stability is relatively good. However, the Inspire II is designed so that no other camera can be installed other than the one that is installed by default at the time of shipment. The standard camera is 24 megapixels and the focal length is 16mm, which is relatively short, so the accuracy of the captured images is somewhat lower.

2.2.2 UAV survey

Since the point cloud generated by SfM (Structure from Motion) technology has relative coordinates between the camera and the object, aerial triangulation must be performed to convert it into absolute coordinates. However, since the low-cost GNSS receiver and the ultra-small IMU (Inertial Measurement Unit) built into the UAV have low accuracy, the accuracy is lowered if the external expression factor acquired due to the factors that greatly change the aircraft's posture is used as it is. Therefore, in order to give accurate absolute coordinates when performing aerial triangulation, GCP (Ground Control Point) surveying is essential (Xu *et al*., 2018). When aerial triangulation is performed, the external expression elements of the camera are accurately obtained, and the three-dimensional coordinates of the features are determined based on this. In order to improve the accuracy of aerial triangulation, the coordinates of the ground reference point must be accurately input during the image processing process, so the position of the ground reference point must be clearly identified on the photo. Therefore, the ground reference point arranged on the road uses the corner point of the road lane clearly identified in the photograph. However, in farmland without artificial facilities, an anti-aircraft sign must be installed before shooting so that it can be clearly identified in the photograph.

Five ground reference points were installed at the target site of this study. The current guidelines for public surveying using unmanned devices stipulate to install more than 9 ground reference points per square kilometer (National Geographic Information Institute, 2018a). Since this site is a narrow area of about 300m in width and length, 5 points were installed, and 5 checkpoints (CP1~CP5) were also installed to determine the positional accuracy of the DEM and orthographic images after image processing.

For the ground control point survey, three-dimensional coordinates were obtained by performing plane reference point surveying and level surveying. Planar reference point surveying was performed using the network RTK method, and leveling was performed using the direct leveling method. Planar reference point survey was performed by network RTK method using SP80 RTK equipment from Spectra Precision, USA. RTK equipment was installed for each reference point, and the arithmetic average of 3 sets of observations for 10 seconds per set was determined as the reference point coordinates. Fig. 3 is a scene where the reference point is surveyed using the road lanes and anti-aircraft signs as reference point marks.

Fig. 3. Control point survey by GNSS

For leveling, leveling was performed by GNSS starting from the integrated reference point U08, which is located near the site, and the elevation of each ground reference point was determined. Table 1 compares the performance of GNSS leveling using the direct leveling method and the national geoid model. As a result of comparison, an error occurred within the maximum range of 2.4cm between the two methods. Currently, the average precision of the national geoid model, KNGeoid18, provided by the National Geographic Information Institute is 2.33cm (National Geographic Information Institute, 2018b).

Table 1. Comparison of performance of leveling and geoid model

Station	Direct leveling(m)	KNGeoid18 (m)	Difference (m)
U08	11.735	11.716	0.019
3274	7.852	7.831	0.021
3275	8.598	8.590	0.008
3276	9.320	9.296	0.024
3282	11.296	11.281	0.015
3283	11.466	11.453	0.013
3287	11.689	11.684	0.005
⋮	⋮	⋮	⋮
B1	7.284	7.269	0.015

Filming was performed using vertical take-off and landing fixed-wing UAV and rotary-wing UAV. This area is an area that is relatively safe and easy to fly because there are no special obstacles such as power transmission towers or tall trees on the take-off and landing lines as there are no special obstacles on the take-off and landing lines. As the shooting plan of the vertical take-off and landing fixed-wing UAV, the shooting altitude was set to 150m, and the image of GSD

2.98cm was obtained using a 24 megapixel Sony A6000.

With a fixed-wing UAV, one shot was taken with an altitude of 150m, a vertical overlap of 75%, and a lateral overlap of 73%. The rotary wing UAV was also photographed by setting the flight altitude to 150m in the same way as the fixed wing UAV. Although the public surveying work guideline for using unmanned aerial vehicles stipulated overlapping images of 65% in the longitudinal direction and 60% in the lateral direction (National Geographic Information Institute, 2018a), in order to increase the matching accuracy, in this study, the vertical overlap was 80% and the horizontal Redundancy of 80% was set.

2.2.3 Image processing

After shooting, the photos stored in the camera's SD card are transferred to the Metashape software. Since the GNSS measurement coordinates mounted on the UAV are recorded in all photos, images are automatically arranged by this geo-tag data. After the images were arranged, the ground reference point performance was entered. Since the ground reference point input is performed by clicking the exact position of the pixel with the mouse, the smaller the GSD size, the more accurate it can be entered.

When the image arrangement is finished, the Metashape software is started, the images are registered using the SIFT algorithm, and an initial point cloud is created by the SfM algorithm. However, the initial point cloud has a low point density, making it impossible to intuitively analyze the topography, so it is difficult to use it directly as survey data. Therefore, in order to use it as survey data, it must be converted into a high-density point cloud using the CMVS / PMVS2 (Clustering view for Multi-View Stereo / Patch-based Multi-View Stereo2) algorithm. First, using the CMVS algorithm, the point cloud decomposed into small clusters is converted to high density through rapid interpolation calculation, and the entire point cloud is densified by matching each high-density point using the PMVS2 algorithm. In addition, when the low density point cloud by SfM is converted to high density by the CMVS / PMVS2 algorithm, a high density point cloud is generated.

Since the point cloud converted to high density is vector data in which all points have three-dimensional coordinate values, various data processing is possible by itself. However, since the point cloud is a vector data format and the dot interval is not constant, it is necessary to convert it into DSM data arranged in a grid of a certain size in order to produce an orthographic image, which is raster data. When the DSM is generated, an orthographic image is generated by projecting RGB data on the grid of the orthographic projection plane corresponding to the position of the DSM grid (Fig. 4).

Fig. 4, an orthographic image, was produced as a fixed-wing UAV image acquired with a GSD of 2.98cm by mounting a camera of 24 million pixels, which has a higher resolution than the image acquired with a GSD 4.11cm rotorcraft UAV.

Fig. 4. Generated ortho-image

When installing the ground reference point, the ground survey is performed using the network RTK method for the 5 checkpoints installed together, and the accuracy of the UAV survey is verified by comparing it with the coordinates extracted from the DSM. Planar surveying uses the network RTK survey method of VRS (Virtual Reference Station) method, and uses geoid data of KNGeoid18 model instead of direct survey for elevation.

In this study, checkpoint surveying was performed by determining the 3D coordinates using the elevation automatically calculated from the KNGeoid18 data file input to the GNSS controller. Table 2 shows the values obtained by subtracting the checkpoint survey performance from the fixed-wing UAV survey performance. As a result of confirming surveying for 5 checkpoints, it can be seen that the maximum error of 30mm on the X-axis, 23mm on the Y-axis, and 68mm on the elevation occurred, indicating that a high-accuracy DEM was generated by the UAV survey.

Table 2. Survey performance of checkpoints by UAV survey

Station	X coordinate (mm)	Y coordinate (mm)	Elevation (mm)
CP1	-23	-23	29
CP2	-12	-1	26
CP3	5	-6	40
CP4	-30	-1	-50
CP5	16	2	68
Average	-9	-6	23

The first terrain model created by raster transformation of a point cloud is DSM. However, in order to calculate the amount of earthworks, DEM, which is pure ground data, is required.

In order to obtain the DEM, it is necessary to remove non-ground data such as vegetation or buildings from the point cloud used to generate the DSM. Fig. 5 indicates that the existing building data was manually removed from the entire point cloud, and the number of point clouds for buildings removed from the total of 20,995,410 point clouds was 11,322,316 points.

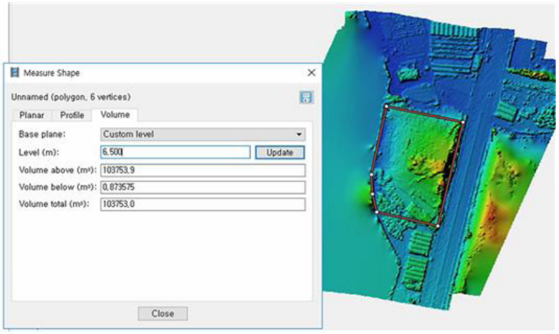
Fig. 5. Remove buildings from point clouds

The area where the building is located is an existing housing complex and has nothing to do with the construction work, so there is no need to rotate the point cloud, and it is all deleted from the plan. The point cloud of the next deleted vegetation was 778,394 points. It took about 30 minutes to remove non-ground point clouds such as buildings and vegetation.

In order to check the accuracy of the generated DEM by removing the point cloud for trees, GNSS ground survey was performed using the network RTK method. As a result of comparing the DEM and ground survey performance for the same point, an error of at least 0.6cm and a maximum of 26cm occurred for a total of 141 points, and the root mean square error was ±9.5cm, indicating a relatively good result.

2.3 Earthwork volume calculation

In the DEM created based on the point cloud from which trees have been removed, if you set the area to calculate the earthwork volume and input the plan height, the total earthwork volume summing up the volumes of each DEM grid is calculated. In Fig. 6, the plan height means the height of the reference plane, volume above indicates the cut amount, and volume below indicates the fill amount.



Unnamed (polygon, 6 vertices)

Base plane: Custom level
Level (m): 6.500
Volume above (m³): 103753.9
Volume below (m³): 0.873575
Volume total (m³): 103753.0

Fig. 6. Earthwork volume calculation program

As described above, the earthwork volume is calculated using DEM, and the earthwork volume calculation report is output based on the orthographic image for easy intuitive interpretation by the client. In the report, the orthographic image of the earthwork volume calculation area, the calculated area, the fill amount, the cut amount, and the total earthwork amount are specified. Fig. 7 is the earthwork volume calculation report format output by the software used.

#	Perimeter(m)	Area(m^2)	Volume above(m^3)	Volume below(m^3)	Volume total(m^3)
1	463.322	13317.7	104362.2	1.423	104360.7
Total	463.322	13317.7	104362.2	1.423	104360.7

Base plane for volume calculation: 6.500m

Fig. 7. Earthwork volume calculation report

3. Estimated Earthwork Volume Analysis

Data were analyzed to verify the accuracy of the earthwork volume calculated using the DEM generated through the UAV survey. First, the amount of earthwork according to the size of the GSD was compared, and then the cross-sectional view was extracted from the design drawing and compared and analyzed with the amount of earthwork calculated by the double-section average method.

3.1 Comparison of earthwork volume by fixed wing and rotary wing UAVs

The amount of earthwork was calculated and compared using the DEM obtained by setting the vertical take-off and landing fixed-wing and rotary-wing UAVs to the same height of 150m. The GSD of the image acquired with the fixed-wing UAV is 2.98cm, and the GSD of the image acquired with the rotor-wing UAV is 4.11cm. Based on this, the amount of earthwork was calculated by the software.

The amount of earthwork by vertical take-off and landing fixed-wing UAV was 103,393㎥ and that by rotary-wing UAV was 103,758㎥. Since the difference value is very small, it is judged not to be significant. The DEM grid is created with the same size as the size of the captured GSD, and the height value of the DEM grid is determined based on the elevation of the highest point among the areas of the grid. Therefore, if the GSD is large, the grid volume is calculated to be large because a high value of elevation is applied to an area larger than the area occupied by the image with a small GSD. As a result, it can be seen that as the area of the DEM grid increases, the volume increases in proportion to the increase in the size of the DEM grid because the large GSD value does not represent the topographic relief in detail.

Since the target site of this study was not large in scale and the topography was small, the difference in the amount of earthwork did not occur. It is considered that there is (Cho *et al*., 2016). Therefore, in order to accurately estimate the amount of earthworks in the future, it is necessary to take high-resolution images with a low possible GSD value.

3.2 Analysis of earthwork volume change according to GSD size

In order to closely grasp the increase or decrease in the calculation of the earthwork volume according to the size of the GSD, the earthwork amount was calculated by arbitrarily adjusting the GSD of the rotorcraft UAV image. In order to take pictures with different GSD sizes with the same camera, it is right to fly several times at different altitudes.

Table 3 compares the GSD 2.98cm obtained with the fixed-wing UAV and the GSD 4.11cm image obtained with the rotary-wing UAV, and the amount of earthwork obtained with the enlarged 5cm and 10cm images.

Table 3. Comparison of calculation of earthwork volume according to the size of GSD

GSD size (cm)	2.98	4.11	5.00	10.00
Earthwork volume(m^3)	103,393	103,758	104,252	105,667
Increase/decrease in earthwork volume	–	reference	+0.47%	+1.83%
Increase/decrease in earthwork volume	reference	+0.35%	+0.83%	+2.20%

The amount of earthwork was calculated based on the DEM generated by adjusting the resolution of the rotorcraft image taken with the original GSD 4.11cm to 5cm and 10cm, respectively. As a result of the calculation, the earthwork volume increased by 0.47% to 104,252㎥ in the GSD 5cm image compared to 103,758㎥ calculated by the GSD 4.11cm image, and increased by 1.83% to 105,667㎥ in the GSD 10cm image.

On the other hand, when comparing with the fixed wing image of 2.98cm GSD, the amount of earthwork increased by about 0.35% in the GSD 4.11cm image, 0.88% in the GSD 5cm image, and about 2.20% in the GSD 10cm image (Fig. 8). Through this experiment, it can be seen that as the size of the GSD increases, the amount of earthwork increases. In addition, in the case of an image with a GSD of 5cm or less, there was no significant difference compared with the earthwork amount according to the GSD of less than that, but a large difference would occur in an image with a GSD of 10cm or more.

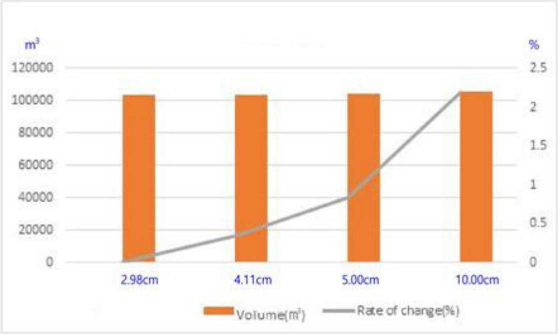


Fig. 8. Earthwork volume change according to the size of GSD

3.3 Comparison with earthwork volume of design drawings

Since the site is a part of the entire construction area, the partial earthwork volume for this is not shown in the quantity calculation report. Therefore, in this study, a cross-sectional view was created using the topographic data of the design drawings, and the earthwork volume was calculated using the double-section average method, and the difference with the DEM-based earthwork volume by UAV survey was compared. The cross-sectional view was produced in CAD by extracting the three-dimensional coordinates of the terrain located on the cross-section from the 2D design drawing. For convenient intuitive interpretation, cross-sectional division lines were made at intervals of 20m from No. 0 to No. 7 in the orthogonal image generated by UAV survey (Fig. 9).

Fig. 9. Show cross-sectional positions on ortho-images

Fig. 10 is a cross-sectional view created based on the design drawings, showing the cross-sections of No. 1, No. 3, No. 5, and No. 7 among them.

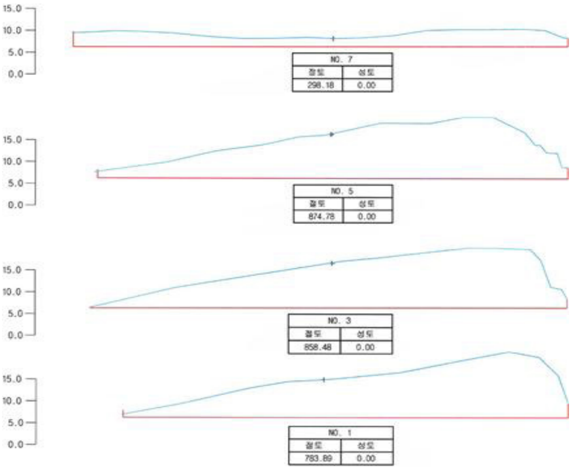


Fig. 10. A cross-sectional view extracted from a design drawing

Using the cross-sectional area of the eight sections obtained in this way and the distance between each section of 20m, the amount of earthwork for the entire area was manually calculated by the double-section averaging method, and about 104,763m^3 was obtained. The amount of earthwork automatically calculated using the GSD 2.98cm fixed-wing UAV image was 103,393m^3. Therefore, the difference in the amount of earthwork calculated by the two methods was 1,370m^3, showing a difference of about 1.3%. In general, in construction sites, if the difference between the amount of earthwork calculated by design survey and the amount of earthwork calculated from construction survey is less than 3~5%, no design change is made. Therefore, it can be seen that the earthwork volume calculated by UAV survey is not significantly different from the earthwork volume calculated by the design drawings.

3.4 Comparison of DEM performance and double-sided averaging results

The earthwork volume calculated by the double-section averaging method of the DEM data generated by UAV survey was compared with the design earthwork volume. DEMs generated from UAV surveys can be transferred to Global Mapper software to automatically generate numerous cross-sectional views at very tightly spaced intervals. However, although it is possible to calculate the amount of earthworks with high accuracy, there is a disadvantage in that the time required for drawing preparation or performance arrangement increases in proportion to the quantity of cross-sectional views.

Therefore, in this comparison, cross-sectional views were created at 20m intervals as in the design earthwork quantity calculation process and the earthwork quantity was calculated using the double-section average method. Fig. 11 shows the cross-sections of No. 1, No. 3, No. 5, and No. 7 among the eight cross-sections generated using the DEM generated by UAV surveying.

The difference between the volume of earthwork calculated by the double-section averaging method using the cross-sectional view obtained from the design drawings and the amount of earthwork calculated by the double-section averaging method was compared using the DEM generated by the UAV to produce a cross-sectional view. The total earthwork volume calculated using 8 sections obtained by UAV survey was 105.929m^3. Since the total earthwork volume according to the previous design drawing was 104,763m^3, the difference between the total earthwork volume calculated by the two methods was 1,166m^3, which occurred about 1.1%. This is also a small difference within the general range allowed by the construction site.

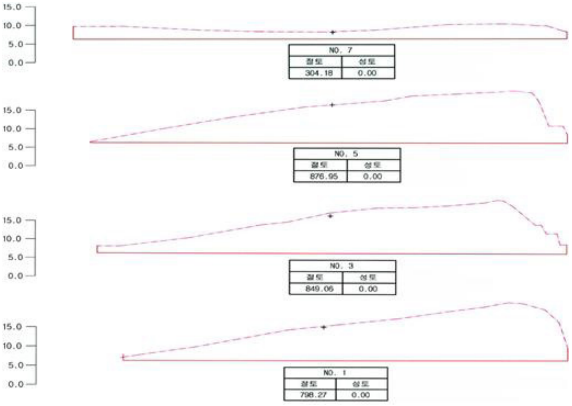


Fig. 11. Cross-sections created by UAV surveys

4. Conclusion

The following conclusions were obtained through a study to efficiently calculate the amount of earthworks based on DEM using UAV.

First, the amount of earthwork calculated based on each DEM generated using the fixed wing and rotorcraft UAVs is 2.98cm for the fixed wing UAV image taken at the same altitude, and 4.11 cm for the GSD of the rotor wing UAV image. The amount of earthwork by the small fixed-wing UAV was calculated to be about 0.35% less than that of the rotor-wing UAV with a large GSD value. In addition, when the GSD 4.11cm image of the rotary wing UAV was changed by using the GSD 2.98cm of the fixed-wing UAV as a comparison standard, the earthwork volume increased by 0.83% at GSD 5cm and by 2.20% at GSD 10cm. When the GSD is less than 5cm, it is shown that there is a slight difference of less than 1% compared to the earthwork amount of the image with the GSD value below that. Based on this, it is worth considering that the GSD standard for UAV images should be 5cm or less for future earthwork calculations.

Second, as a result of comparing the earthwork volume calculated using the DEM generated by UAV survey and the design drawing based on the design drawings, the difference between the two methods was found to be about 1%. However, since the site of this study was small, more research is needed in large-scale earthworks in areas with many undulations and dense trees.

Third, using DEM data by UAV survey, the amount of earthwork calculated by the double-section averaging method was compared with that of the design drawings. As a result, there was a difference of 1% between the two methods. This suggested the possibility that the earthwork volume estimation method using UAV can replace the existing method.

However, since the current system stipulates that earthwork volume is calculated using only the cross-section average method, even if 3D design is made based on DEM data in the future, it is difficult to apply the earthwork volume calculation method using DEM in reality. Therefore, in order for the earthworks quantity calculation method using DEM to be applied to BIM (Building Information Modeling) design or construction, it is necessary to include this method in the quantity calculation standards such as construction design guidelines or standard product counting.

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