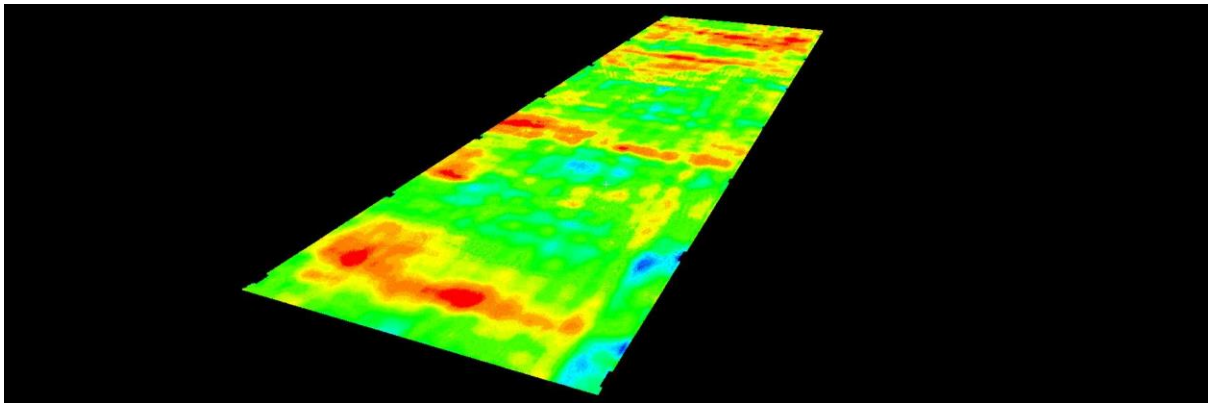
# Our first experience working alongside 3D scanning to check floor flatness compliance on a live project for a Robotics picking facility running on a composite metal deck.

**Kevin Dare – Managing Director – Face Consultants Ltd** **26th April 2021**



*3D heat map of a typical mezzanine metal composite deck floor. "Pretty pictures"*

On a recent project, planned for a Robotics fulfilment centre with composite metal decks mezzanines, the specialist flooring contractor was persuaded to employ a company to 3D scan the floor to check compliance with the required flatness specification on the basis that the 3D scanner solution would be quicker and more detailed than the current profileograph method the flooring contractor had employed on the last 7 projects they had successfully delivered to budget and on time.

The 3D scan presentation given by the survey company did look impressive with all the "pretty pictures" it generates, state of the art equipment and latest jargon, together with a promised, near just in time delivery of scan, error marking, grind and pass off. The reality however did not meet these impressive claims.

For those who understand 3D scanner setting up and accuracy in use, here are some site observations of the scanning process used on site to survey just over a 2,400 square metre bay per day and 21 bays per floor level:

- Leica P40 Scanner used
- Scanner set up on a dolly for ease of site movement.
  - 4 control points at either end of each panel length with another 4 control points on columns in the middle of the panel length. Panel length is about 150 metres long and 16 metres wide.
  - Picking the control on the scanner from the first setup near the initial and last control points and then cloud to cloud registration on the rest.
- Scanner set at around a 2-minute scan time.
- Scanner set max. 10 metre centres.
- Total scan time for 2400 sq. m was about 3 hours.

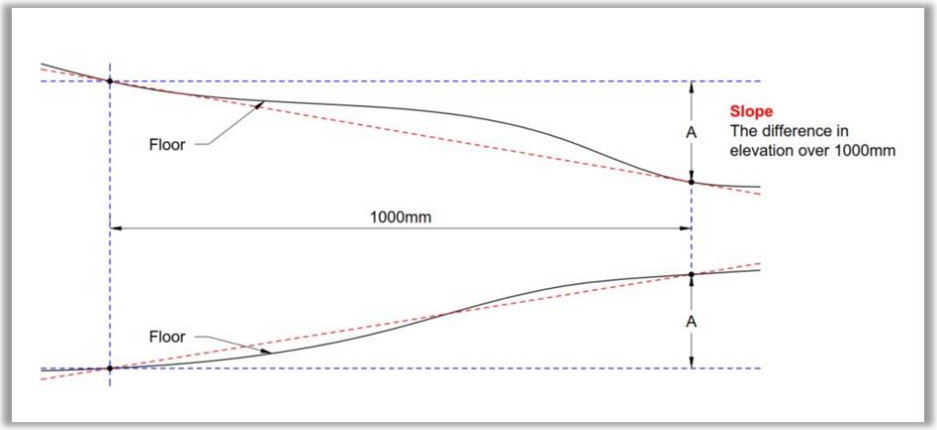
Once scanned, the data was taking about 2 to 3 days to process, to generate an error plan. The survey team then marked the location of the errors on the floor for corrective grinding by an experienced grinding crew.

The first part of the process, after scanning, is to take the point cloud data and to produce a 50mm x 50mm grid of elevation readings over the whole of the floor. Each elevation reading is based on the average of all the data within each 50mm x 50mm square. Those grids of elevation readings were then used to produce differential elevation readings and rates in change of differentials at 50mm intervals in each direction of the grid. The Properties of flatness / levelness that form the surface regularity specification are detailed below.

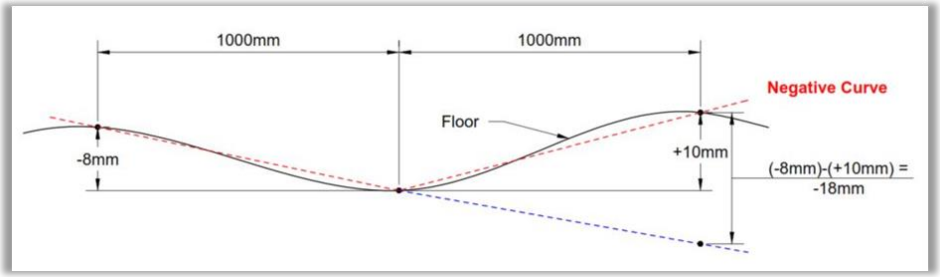
An error plan was then generated showing where the following properties limits were exceeded. This error plan was used to mark the floor and passed to the specialist grinding crew to bring the floor back to specification.

The properties of flatness and levelness on this project were:

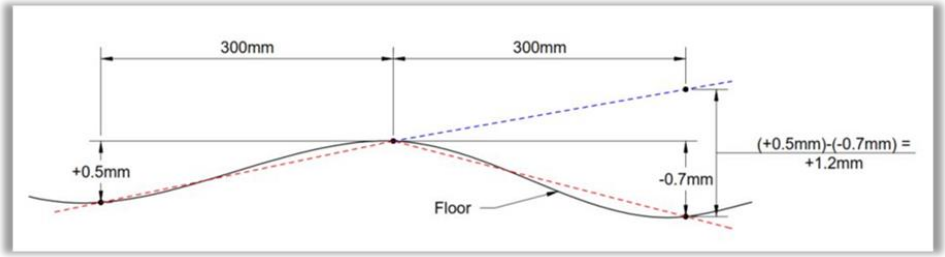
**Property 1**




**Property 2**




**Property 3**

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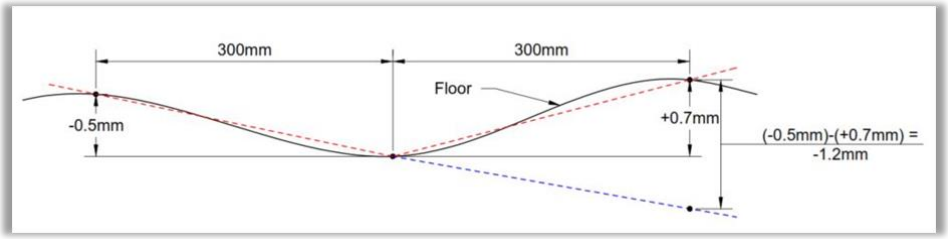
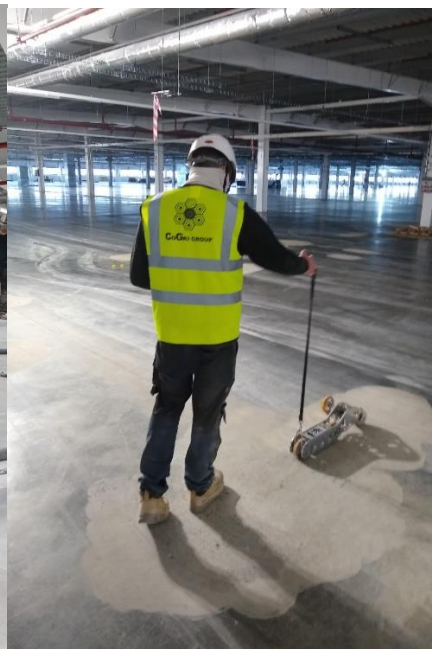
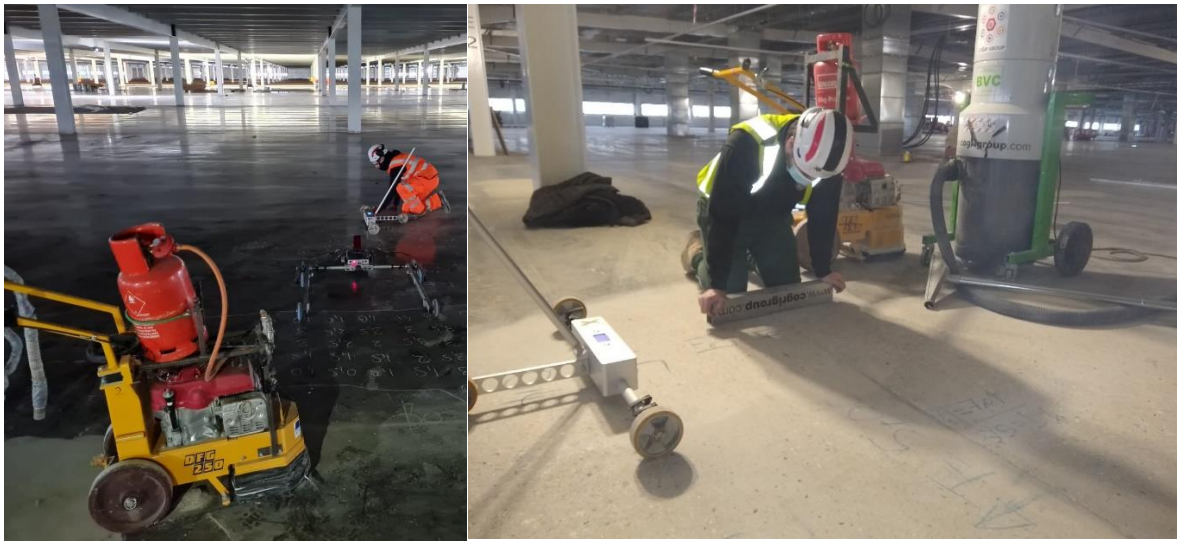



The maximum values of the properties were reduced to accommodate an uncertainty value (inaccuracy) of the 3D scanning process. The value of uncertainty declared by the scanning company on this project was **0.8mm**. Although this maybe the uncertainty of the z value (optimistic) it is not the uncertainty value that should be used for each of the property limits, but 0.8mm was used on all 3 properties.

It was found that Initial scans were next to useless producing error plans that were horrific. It was deemed by the 3D scanning company that this was due to the floor not being clean enough when scanned.

After a few days grinding, the experienced grinding crew started to ask questions as to the validity of the survey as they were struggling to find a lot of the errors that were marked. After about 4 weeks on site and struggling with the unusual volume of grinding works and a lack of onsite direction from the 3D scanning company, the Grinding crew decided to call in Face Consultants (Face) with their profileograph, with whom they are used to closely working with on previous projects, to help them validate the errors. It was found that 40% to 60% of the errors marked by the 3D scanning crew were in fact false positives. There were also errors not found with the 3D scanning process (false negatives). Probably due to the uncertainty level being set too low.





*Top left, clockwise: Controlled grinding. Checking grinding with Prop II meter. Marking errors with profileograph and Transbar. Checking grinding with straightedge and Transbar.*

Discussions were had between the flooring contractor and the 3D scanning team and it was decided that they would now analyse the floor on a 1 metre x 1 metre grid over the whole of the floor. Although this reduced the number of errors being marked on the floor, there were still the same number of false positives in terms of a percentage marked. Face was retained by the grinding crew to validate the marked errors using the profileograph and other digital surveying equipment at their disposal. False positives were not ground but noted.


*Profileograph used to mark required grinding.*

We found that one of the main problems with the 3D scanning process was workflow and process time. Below is a typical workflow documented on this project:

Day1 – Clean and prepare the floor for scanning.
Day 2 – If the floor had not been contaminated by contractors walking over the cleaned area or stored equipment, the floor was scanned.

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Day 3 to 5 – Analyse data and produce error and grinding plans.
Day 6 – Floor was marked for grinding and grinding commenced.
Day 8 – First stage grind complete and floor cleaned for scanning. Floor had to be cleaned and handed over to the 3D scanning team by 12.00pm to secure a scan time slot the following day.
Day 9 – No scan as slot not booked earlier enough the day previous.
Day 10 – Re-scan
Day 11 to 13 – Analyse data and produce error and grinding plans.
Day 14 – Floor was marked for grinding and grinding commenced.
Day 15 – 2nd stage grind complete and floor cleaned for scanning. Floor had to be cleaned and handed over to the 3D scanning team by 12.00pm to secure a scan time slot.
Day 16 – No scan as slot not booked earlier enough the day previous.
Day 17 – Re-scan
Day 18 to 20 – Analyse data and produce error and grinding plans.
Day 21 -– Floor was marked for grinding and grinding commenced.
Day 21 – Final stage of grind complete with last bit of tickling in and floor cleaned for scanning. Floor had to be cleaned and handed over to the 3D scanning team by 12.00pm to secure a scan time slot.
Day 22 – No scan as slot not booked earlier enough the day previous.
Day 23 – Re-scan
Day 24 to 26 – Analyse data and hopefully produce a passing report. Hopefully.

After 3 months grinding on site and not a single bay passed off, and hand over dates looming, the flooring contractor finally gave in with the 3D scanning process and instructed Face to profileograph survey 2 of the 3 floors. 3D scanning continued on one of the floors utilising a grinding crew nominated by the 3D scanning company.

The first half of one floor was profileograph surveyed over a single weekend using 8 profileographs. 5 days later the first 12 bays were ground and passed off as compliant. Face was then moved onto the second half of the same floor which was again tested, ground and passed off in about a week. Face then moved to the second of the three floors and worked hard with the grinding team to get this passed off within 3 weeks.

Both floors were profileograph surveyed, ground, and passed off within 5 weeks of instruction. Both handed over 1 week before hand over dates but still three weeks behind program.

*2 of the 8 profileographs used over the weekend to survey 28,000 sq. metres of floor (1m x 1m).*

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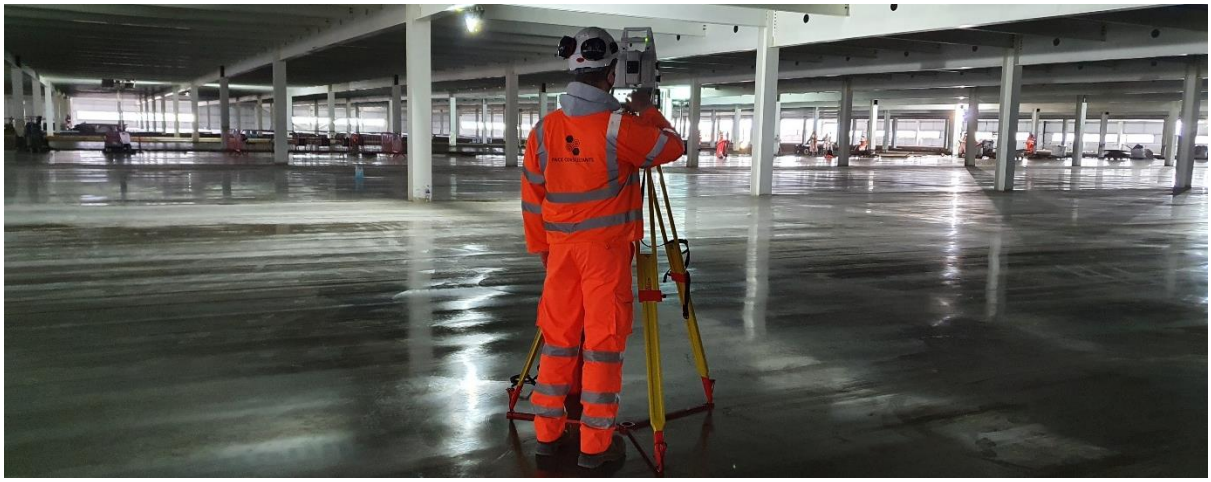
The 3D scanning process remained on one of the floors where it took 11 weeks to scan, grind and pass of 10 bays (Phase 1) just handing over before the contractual hand over date for that phase and 4 weeks behind program. It took just 2 weeks to scan, grind and pass off the final 11 bays, completing works the night before the handover date date of that floor. Again 4 weeks behind program.

To give you an idea of a typical workflow of what has been, and currently happening, on similar sites in the UK and EU where the profileograph is used for checking surface regularity compliance:

2 days after casting the floor it is surveyed with the profileograph.
The floor is broom cleaned and is done so just in front of the profileograph. The whole bay does not need cleaning in advance.
The process will tolerate light dust.
The profileograph is run at maximum 1 metre centres in both directions. This takes the best part of a day to complete 2400 square metres.
The results are instant and viewed on a laptop on site.
The floor is marked for grinding the following day and grinding commences.
Grinding patches are checked as soon as they are ground, with a profileograph surveyor working closely with the grinding team.
The floor is checked as soon as grinding is complete and re-marked immediately if needed or signed off immediately if it is passing.
As the uncertainty value is less with the profileograph, the property limits are greater. This means less grinding.
There are no false positives assumed, all errors found are ground.
Floor grinding is currently taking about a day per bay (2400 sq. m), keeping up with the floor construction program and well before following trades.

Face Consultants have set up a 3D scanning division to explore the best equipment and processes to survey floor surface regularity against current specifications and have already developed software to help in this regard, but we are still some way off a workable and timely system we are confident in using.



*Face Consultants 3D division with Leica P40 and total station.*

Along with the challenges of reducing uncertainty from the data collected, other challenges still need to be overcome before we (Face) can feel comfortable using this system for surface regularity compliance checking with any degree of confidence:

1. Uncertainty values to be determined. Not just the uncertainty of the z value but uncertainty of the properties of surface regularity being tested which may involve a differential of 3 elevation (z) values.
2. What 'property' uncertainty value should be used to ensure we pick up all the false negatives? The greater the uncertainty value, the greater the number of false positives that will emerge. The lower the uncertainty value, the greater number of false negatives will be missed. The more errors shown on a survey the more validation work will need to be carried out to prevent unnecessary grinding. This requires more time on site, thus increasing the program.
3. Looking at a slot in the program that allows the floor to be cleaned and remain clean during the survey and grinding process. This is usually difficult when the need to meet a tight program results in the survey being caried out close to the operational floor construction face.
4. To speed up the time it takes to process the point cloud data and produce usable information to determine guidance for remedial action if there is noncompliance with the specification. 2 to 3 days is just too long.
5. How to validate the errors generated by the scan to ensure that grinding is not carried out unnecessarily. What equipment should be used to validate if the 3D scanner is not accurate enough?
6. How to change the values in a final 3D survey report when a false positive is identified with a separate piece of equipment. What values go into the 3D scan compliance report when the scan itself shows noncompliance, but another piece of equipment has validated compliance? Will a simple statement of compliance from a credible survey company, without proof of data, be acceptable?
7. Who has the authority to accept and sign off false positives when found?
8. What is the correct resolution of data for floor compliance? The specification currently looking at a single elevation value in the middle of a 50mm x 50mm square where the z value is an arithmetical average of the data within that square. Having uncertainties at this resolution means a lot of validation work to be carried out to prevent unnecessary grinding.

The profileograph currently takes lines of data set a maximum 1 metre apart (could be any dimension) where the lines are laid in orthogonal directions over the whole of the floor. Each

property is measured every 50mm movement along the survey line. Current 3D scanning is being analysed on a 1 metre grid in a similar manner.

You will now understand my reluctance to go down the 3D scanning route to contractually check compliance to floor flatness specifications at this present time. A check that determines whether a flooring contractor gets paid or not.

Using the 3D scanning method on this project has resulted in:

- Program not being met.
- Completion too close to contractual hand over dates due to program not being met.
- A question as to whether the specification has been met, due to uncertainties.
- A validation process being introduced which complicates reporting and getting pass off.
- Not picking up false negatives because uncertainty levels being set too low.
- Unnecessary grinding due to false positives
- Clashing with following trades due to program
- Corrective grinding costs tripling that of previous projects.
- Surveying cost, well over budget.

We have looked at using, and trialled, the Hexagon (Leica) ATS 600, and it is an impressive bit of kit, and has proved to be as accurate as the profileograph, with better resolution and might solve some of the uncertainty issues of the 3D scanner. However, it does not get rid of the workflow and program problems that we currently have with 3D scanning. Some further work is needed in this regard before we (Face) feel comfortable using 3D scanning to check contractual compliance. Great for "pretty pictures" and a general overview of overall levels, but contract compliance? More work is needed.

*Leica ATS 600*

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