SPECIFYING ALTERNATIVE TILE INSTALLATION SYSTEMS- AN EDUCATED DECISION, OR DECISION THAT EDUCATES?

Tim Christopher

Consultile, Australia.

BLOCK B SUMMARY SUBMISSION:

Tile installation systems have developed significantly with the introduction of new technology. Elements such as tile format, acceptable substrates, installation, building methods, and materials are all evolving aspects of tile installation systems. These elements vary from nation to nation and various regions within them. Some nations have developed, adopted, and implemented various tile installation methods and supporting test methods standards as deemed necessary to their specific location and building methods. However not all nations have made the same progress in relation to the development and implementation of new tile installation systems. Applicable supporting test methods, related manufacturing and building standards which may restrict certain developments in tile installation systems, vary greatly from one location to another.

Architects, importers, specifiers, builders, and contractors can adopt and implement tile installation systems or elements of a system from another global location. This can be an effective way for multinational building contractors to use new technology and processes to overcome issues such as building timelines, incompatible products, and internationally sourced specified designs.

The risk in implementing research and development from another nation for a tile installation specification, is that there are supporting standards, codes, test methods, manufacturers documentation and intellectual research which back the specification detail of these systems. These associated items are not always fully identified, understood and/or implemented when used as an alternative system.

Language barriers, import restrictions, test methods or even basic training and understanding can negatively affect the entire alternative installation system from being successfully implemented.

Ambiguity means that there can be no local knowledge base, documentation, manufacturer support or certified testing facilities available to provide clarity or a guidance. Often, overlooked or misunderstood elements only become apparent after failures occur. The subsequent analysis to establish cause and apportioning fault is an intensive, problem-solving discovery exercise. The original specifier of the system is of little assistance if they contributed to the problem through lack of understanding of the system in the first instance. This works as a post project educational process with unfortunate costs of rectification.

Contributing elements to such failures can be:

- partial or incomplete specifications;
- incorrectly interpreted installation and performance specifications;
- elements of a system substituted through lack of availability;
- systems which cannot be verified as appropriate as all the supporting standards do not apply or are unavailable/overlooked in the specification process;
- lack of or insufficient product support at the location in which the installation is implemented;
- lack of a full suite of standards being available.

After a system failure, there is the potential for further obscurity when re-interpretation occurs of select standards and guidelines to prevent and defer liability. Only when full and complete system installation characteristics are known is the cause of failures. This is a costly way to implement an alternative tile installation system.

MOVEMENT JOINTS

Movement Joints are common elements in construction which require consideration when specifying and installing tile and stone projects. Newer more modern approaches to eliminate and provide relief within the tile installation for various control joints, cold joints, dowel joints and construction joints have led to the development crack suppression systems. These are commonplace in areas of Europe and North America, however in regions such as Australia and New Zealand these systems are relatively unused or unknown. Crack isolation systems are often specified to overcome issues relating to new concrete slab construction and existing concrete slab characteristics such as cracking which would otherwise be difficult to accommodate. The elimination and or/relocation of movement joints using concepts such as deformability and de-coupling from the substrate can prevent some types cracking and eliminate the requirement to install where movement joints at some locations when a tile is bonded directly to a problematic substrate.

Crack suppression systems have been manufactured and developed along with compatible installation standards and test methods for the individual products. These standards also need to be considered as part of the specification. Many solutions are sourced from other locations such as the USA where new products and methods have been developed.

Projects with large floor areas may have multiple joints such as dowel joints, construction joints and cold joints. New and existing concrete slab types can be brought together to reconfigure projects such as shopping malls. When slab joints and movement pressure are sought to be accommodated and eliminated, the international market is a source of solutions. An architect and engineer will often specify a crack suppression system from a US manufacturers product range. The data sheets for these products will often specify parameters such as '*40 mil thick load bearing membrane, capable of 1/4" (6.4mm) crack isolation protection*' [2] This information is then taken as a specification to accommodate cracks and joints with movement up to 6.4 mm (1/4") [2].

Further direction within the same data sheet example states; '*Eliminates need to cut tile to meet control/cold joints*' [2]. Subsequent direction to the contractor from the architect is that the use of the referenced product is a solution to the implementation and presence of various floor joints present.

Problems begin to arise (see photograph 1) because the product specified is not available nationally or is substituted with a similar product expecting a corresponding performance requirement. Additional elements such as primers, leveling compounds, and adhesives which have been tested with the specified crack suppression system may not be available or sourced as a portion of the complete system. Similar locally available components are often sourced to make up the shortfall to implement the installation.

Photograph 1*-Commercial shoping centre cracking in quartz tile at a cold joint location.*

A secondary issue is the tile type used over the crack suppression system. During the pre-construction process there are often several changes to the tile selection as budgets and design requirement are refined. This can cause a creep in the changes of the installation design requirements which isn't always noted. Substituting porcelain for various types of stone tiles adds complexities to the design requirements. As stone is sensitive to other environmental conditions, new aspects need to be considered which were previously not items of concern. Exposure to UV light, the presence of moisture, slab design, and deflection values are all issues which alter the original specification when compared to using a ceramic/porcelain tile.

The understanding of the type of movement that is present is a common problem when crack suppression systems are specified. The ability for these systems to accommodate movement is sometimes taken by designers to mean all movement. The difference between in-plane movement and vertical and multi directional deflection is also often overlooked.

***Photograph 2**-Commercial shopping centre slab joint where crack isolation system failed to prevent cracking where the architect specified joints in tiles were not required.*

Onsite parameters relating the nature of the movement experienced may not be applicable to the alleviation provided by the crack suppression system (see photograph 2). These differing movement types such as vertical and twisting movement are not something crack suppressions systems are necessarily designed to accommodate.

When subsequent problems arise, there is a complex evaluation required as to what has caused failure. Substituted products or partial elements of complete systems within the specified design are then identified as caused of failure. Often the technical representation of the local product supplier with a suitable engineering background is not available. Subsequent evaluation of the failure frequently requires reference to unrelated third parties who don't have access to inhouse proprietary testing or information of specific products.

WATERPROOFING IN POOLS

Recent pool tiling systems often contain waterproofing membranes as a part of the overall specification. Most major tile product tile adhesive/installation manufacturers now recommend a waterproofing membrane be installed as a component of the tiling installation, particularly in commercial pools. While there are pools constructed where membranes are not utilised, in the instance of failure within the pool the installation system will come under scrutiny.

If there is a tile delamination, elements such as, movement joints and the concrete shell construction are usually the primary areas for investigation. Often, when the system used to install the tiles within the pool is examined it is not unusual to find some critical elements are omitted or substituted due to costs. An architect or engineer may delete an element such as a waterproofing membrane on the grounds that it isn't a mandatory addition or that the pool shell is of sufficient engineering design, as to not require a membrane.

A recent pool construction project in Australia was subject to a warranty claim against the head contractor due to tile delamination. The absence of a waterproofing membrane was considered as to what impact it may have had on the tile failure within the pool. The omission of a membrane as part the specification process was an alteration to the original scope. Most of the elements used to install the tiles inside the pool were not available in Australia and were sourced from multiple different manufacturers product lines internationally. After the failure, a similar system, excluding a waterproofing membrane was put forward as a specification for rectification.

The rectification system relied on elements from a German adhesive manufacturer whose product was to be used to rectify selected pool walls and the pool base.

On considering the documentation and applicable design elements, the following problems were identified:

I. A search was undertaken of the manufacturer's website, and it was established that the products are not supported by a commercial entity or managed supplier within Australia. As such, the specifier and assessment of suitability of products fell to the pool tiling contractor. The product data sheets supplied by the contractor included referencing a '*Tiling in Swimming Pool Construction'* guide which subsequently listed the 'DIN' [4] series of standards as applicable to the manufacturers system when used within a pool. This is a standard established for Construction within Germany and is not part of any standard or code within Australia.

II. The DIN [4] standards are written in conjunction with compliance with the ZDB (Federation of German Construction) guidelines. While these are German guidelines and standards, they apply to the manufacturers products when utilised for a pool tile installation and subsequently are required to be followed. There are no Australian Standards or BCA (Building Code of Australia) Codes referenced on manufacturers data sheets or guidelines for swimming pool installation which would override or substitute the manufacturers specification and supporting standards.

III. The DIN standard 18535 and ZDB guidelines which relate to swimming pool construction outline the installation requirements of a waterproofing membrane inside swimming pools. This also is outlined in the Manufacturers [1] 'Tiling in swimming pool construction' guide. (See excerpt below, 'Tiling in Swimming Pool construction' guide.) "…*Based partly on the ZDB data sheets "Composite waterproofing systems" and "Swimming pool construction", the new standard DIN 18535 "Waterproofing of tanks and pools" among other things describes liquid-applied waterproof membranes for use in conjunction with a tile finish, which now has the status of an officially standardized system…" [4]*

IV. Omitting to install a waterproof membrane as an element to rectify the pool would not comply with the manufacturers recommendations or provide a construction configuration for which the products are designed.

V. As the complete product range for the rectification works was not available locally, alternative additives and primers sourced from within Australia were used to complete the gaps in the installation specification.

If the proposed specified installation was implemented, it would effectively be a patch work of materials with untested compatibility, consisting of various primers, adhesives, grouts, and additives, all which are not supported by manufacturer's warranty within Australia. The products would not to be installed in accordance with the manufacturer's specifications specific to the pool, nor in accordance with the DIN standards [4] and German based guidance for pool tiling installations on which the manufacturer is basing the methodology. It is difficult to see how the system could be assessed accurately or comprehensively for any substantial performance guarantee on the rectification works.

SUBSTITUTION WITH STONE TILE

Stone tiles are often specified for commercial flooring installations and are sourced from all around the globe in lieu of Porcelain and ceramic tile. Natural and manmade stones provide a desirable option for architects due to characteristics such as the ability to be polished smooth, unique appearance and durability. Specialised adhesives and components such as crack isolation systems may be required to successfully install tiles and accommodate site specific characteristics such as substrate design. The use of a stone tile adds to the complexity of the installation specification as there may be multiple installation elements which need to be considered and subsequently a highly installation specific hybrid can be created.

Stone thickness, bedding/ adhesive types, finished floor levels, slab movement, cracking, movement joints, and other environmental influences all require accommodation with a compatible stone installation system.

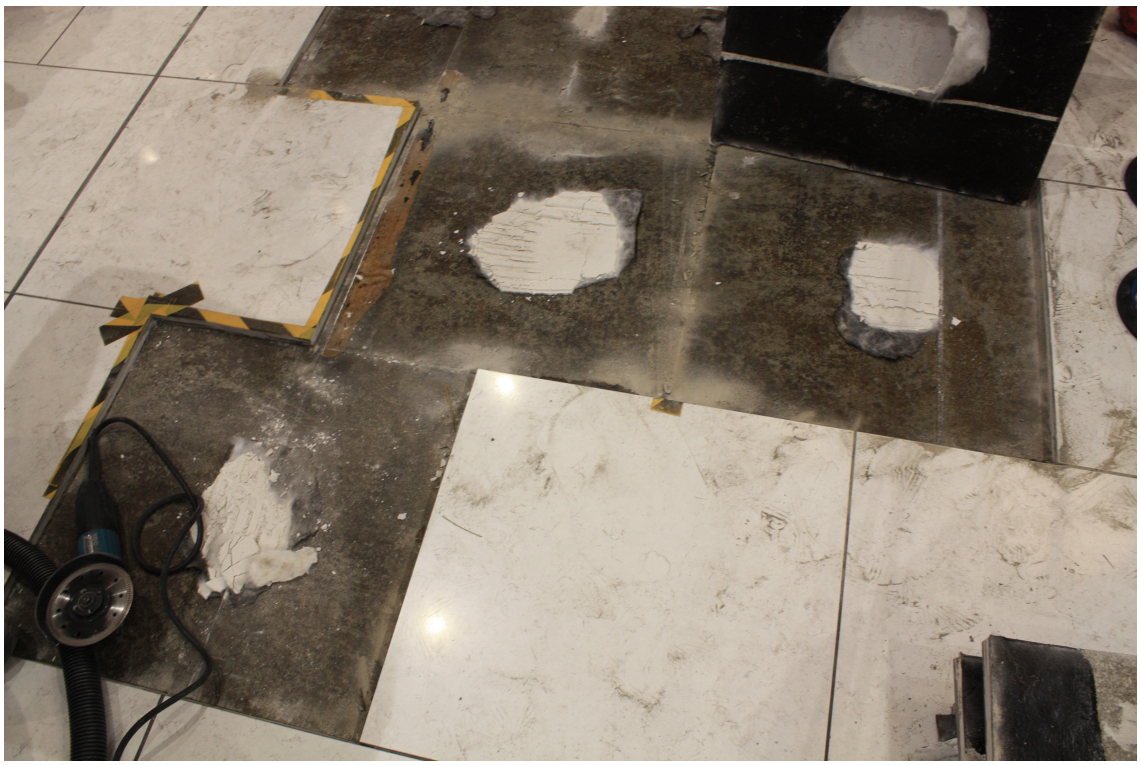
Many additional considerations are added when products such as manmade or 'engineered stone' are substituted for a commercial installation over a more stable porcelain or ceramic tile. UV light, moisture, cleaning regimes and general wear on the stone can impact the longevity of an individual installation where traditional tiles would not be affected. Sourcing elements of an installation system from alternative locations adds risk of miscalculation or component omission to accommodate all the site-specific influences. Moisture sensitive stone is an example of a tile which requires a full and complete installation assessment for a successful installation.

Specifying some types of adhesives or crack suppression systems may lead to engineering additional problems into the installation instead of improving it. Installing moisture sensitive stone onto some crack suppression mats can create additional issues not present when substituting for porcelain or ceramic tile. For example, curling and cupping through exposure to UV light, heat and/or moisture will cause these types of stone to deform as some substrates have reduced or insufficient capability to restrict vertical shear movement that can be present when stone tile curls and warps. These considerations are not required when installing a porcelain or ceramic tile and can lead to tile failure through delamination from the substrate when elements within the installation are sourced in isolation or not fully understood. Often the associated test methods which apply to the individual products are not considered when the specification is put together. In many cases once a failure has occurred, workmanship is regarded as the cause of failure. If the contractor has achieved the recommended installation requirements such as adhesive coverage and movement joint installation, there is subsequent confusion on why the tile installation is experiencing problems.

Retrospective testing for moisture sensitivity and attempted shear tests for adhesion can be carried out on a stone tile and often re-interpretation of various associated moisture tests subsequently leads to inconclusive, misleading, and misinterpreted results.

Conducting moisture tests for longer periods than the test method criteria states in the methodology to determine tile characteristics in relation to behaviour in the presence of moisture, can produce highly speculative and incomplete conclusions. As an example, the *Agglomerated stone-Test methods Part 12 Determination of dimensional stability EN14617.12 2012*[7] is a test is '*mainly performed to classify the material according to the degree of sensitivity to water and to select a suitable adhesive for the correct learning of agglomerated stones.'* This test is not designed to measure the performance of stones in continued and intermittent moisture exposure periods measured over months or years. The test is also caried out with a cloth sample pad as the test background. Extrapolating test results to other substrates such as crack suppression mats and applying moisture reactions to predict long term performance is speculative. These types of issues are examples of interpretation which can occur once failure has occurred, the cause of failure is unknown and new product specifications are used improperly. These issues can be avoided by the implementation of ceramic or porcelain tile in the initial specification in lieu of stone.

Photograph 3*-Stone tile flooring which has cupped and curled in a commercial shopping centre.*



***Photograph 4**-Engineered stone tile installed on a crack suppression mat and subsequently curled and partially delaminated.*

ADHESIVES

The use of tile adhesives sourced from various global locations has increased in recent years as an alternative method of achieving nominated performance outcomes for reduced cost. Through changing adhesives from two part to single part and general reformulation of mixtures it is possible to supply cheaper adhesives which are also tested by the manufacturer to be compliant with performance test methods ISO13007 *Ceramic Tile Grouts and Adhesives* [5] series of classifications.

Supplying and substituting adhesives which have comparable corresponding classifications such as a 'C' or 'S' ratings imported by third parties is inherently risky. If there is an absence of commercial manufacturer representation available to specify and provide product advice on specific applications when tile installation failures can occur where it can be difficult to establish the cause.

Installing tiles into chemically aggressive environments such as commercial swimming pools can be problematic if the complete performance capability of an individual product is not known. An example of this was observed in a commercial swimming pool in Australia (see photograph 5). There was an extrensive tile failure inside the Olympic sized pool which became the subject of extensive investigations to determine the cause.

The initial observations of the tile installation led to conclusions that tile failure was attributable to excess movement within the pool shell structure and insufficient movement joint installation within the pool. When the adhesive underneath the delaminated tiles was observed, strong shear forces appeared to be present. The profile of the adhesive which remained on the substrate was sharp and angular suggesting the tiles were ripped from the substrate by high pressure.

Photograph 5 – *shows evidence shear forces on the tile adhesive inside a pool where failure has occurred.*

The expansion joints in the pool tiling installation were subsequently deconstructed to determine if they were providing the required relief for the tile installation to withstand the submersed environment. The expansion joints were found to be sufficient and compliant in their placement and configuration. It was assumed that the installation was failing due to excess movement in the concrete pool shell which could be exceeding the tile installations capability accommodate the movement present.

There were no cracks found within the pool shell. Subsequent engineering reports established that in fact there had been only 2mm (1/16 Inch) movement over the longest 50 metre (54.6 yards) length of the pool. This amount of movement is insufficient to cause the delamination of tiles seen within the pool. Closer examination of the installation of the tiles established the workmanship to be compliant and suitable for a commercial pool.

As the adhesive was the final outstanding component, this was examined in more detail. A simple examination consisting of removing tiles and manipulating the adhesive remnants by hand demonstrated the adhesive to be of a powdery consistency and large portions could easily be ground into a powder by hand. Investigation into the adhesive used led to the conclusion in photograph 6. The adhesive was not commercially available in Australia and had been imported by the contractor. The adhesive installation recommendations had been revised by the manufacturer to restrict the use in commercial pools post after the completion of the failed installation. Furthermore, the adhesive was withdrawn from sale altogether in the country of manufacture sometime after.

Photograph 6- *shows adhesive crumbling into a powder.*

Further destructive analysis of the pool tiling established there were two other adhesives used in smaller quantities in the pool indicating the contractor had substituted alternative products, as supply of the primary product had been insufficient to complete the pool tiling installation. The secondary adhesives were identified and found to be well adhered and not failing to adhere the tiles inside the pool where they had been utilised. Failure was confined to the original adhesive supplied by the contractor.

The pool operator was in receipt of the chemical maintenance and testing records to support the correct chemical water balance within the pool had been maintained. The conclusion was that the imported adhesive was degrading in the permanently submerged conditions of the pool and not able to maintain the integrity of the tile installation. There was no recourse available back to the adhesive manufacturer as they maintained no commercial presence in Australia and were not involved in the specification for the pool installation. The pool was rectified with a complete pool tiling installation system available within Australia onto the existing pool shell. The system has been performing without issue for several years post rectification and with no works required on the concrete pool shell.

This failure cost the local government several million dollars (AUD), to rectify and the community the use of a much-needed recreation facility which had only been in use for two years before it failed and rendered unusable due to the tile failure.

CONCLUSION

Overcoming modern day construction challenges is an inherent part of the building process. Obtaining problem solving solutions needs to be a well-considered researched and informed process. Utilising partial and incomplete systems, untested and unsupported products can be a lottery on the end performance of the tile installation. Most products are supported by test methods in which their use and performance suitability is based. If the test methods are not understood and considered as part of the specification process, the product selection can end up being more of a best guess than an improved specification.

Referencing test methods such as the American ANSI 118.12[6] test for testing crack isolation membranes may eliminate the suitability of a tile substitution, such as using a moisture sensitive stone where previously ceramic, or porcelain tile, has been specified. Obtaining partial system components such as adhesives from another nation without the consideration of all the supporting proprietary documentation and methodology is highly speculative. Many manufacturer's guidelines and technical notebooks reference a governmental framework such as National/European standards and have been designed in accordance with them.

Specifying products as a partial component of an installation system for highly demanding applications such as commercial floors where there are construction joints or municipal swimming pools for example, will intensify pressure on any deficiencies in the design specification. Referencing 1 or 2 lines on a data sheet as a specification is not a substitute for a fully evaluated performance review. Movement within joints can be multi-dimensional in their deflection. Taking a documented movement limit which applies to a specific plane of movement from a data sheet is not a substitute for site specific engineering detail and evaluation. Obtaining adhesives which have corresponding ISO13007 *Ceramic Tile Grouts and Adhesives* [5] classifications are not a substitute for a manufacturer's recommendation or approval, and not an indicator of long-term suitability for a fully submersed tile installation.

Many failures such as those outlined in this paper resulted in costs for rectification, down time and inconvenience of millions of dollars which far outweigh the problems which the designer/s were attempting to overcome in the original construction specification. Failures within municipal pool complexes can have political and community impacts when protracted legal battles are conducted to recover costs. The requirements for a rapid rectification to place a facility back in service may mean cost are not recovered at all and subsequently passed on to communities to fund. Asking a community to fund a secondary tile installation is likely to be controversial with potential serious consequences for installers, project managers and flow through to the political level.

Designers, contractors, and specifiers are obligated to make fully informed decisions on substitution and hybrid design choices. Attempting to specify a product which is not represented locally by a manufacturer and is merely imported based on minor consultation or information found within data sheets should be avoided. Product manufacturers have access to in house testing and product formulation which inform the specification of each component. In addition to the inhouse manufacturers knowledge, many nations have limited or no access to the testing equipment which is referenced on the data sheets for the products being specified. Utilising products and systems which aren't available in Australia and New Zealand for example, based on US ANSI test methods can be problematic when tests facilities are not available to verify performance of other system components.

Substitution and specifying an adhesive for use in applications such as a commercial pool based on a separate nations standard and omitting significant components is not a decision most contractors and architects have qualifications or product background knowledge to override and implement. When a failure has occurred, it is difficult to rule out the impact of missing or altered elements when a partial system has been installed. There are usually no alternative site-specific recommendations, engineering repot/detail to verify and support the change made.

RECOMMENDATIONS

Seeking out new and advanced building solutions is the natural way forward for raising the standard of construction of modern building practice. Each nation will push ahead to build higher performing and more aesthetically pleasing construction projects. The crucial aspect to the developmental curve is to maintain longevity and performance in the long term for tiling installations. Specifying and substituting alternative products and methods has risks which must be assessed when treading into new frontiers of tile installations. To help safeguard against problems arising when implementing new installation systems, the following steps will assist in strengthening safeguards;

1. The complete proposed installation system should be researched, and specific advice obtained from the country of specification. Obtaining a single or partial portion of the installation system should be verified for suitability by the manufacturer.
2. Test methods that are referenced on data sheets and supporting product documentation should be evaluated to consider the role they play in limiting and defining the performance of the tile installation system. The test methods will ideally outline limitations for elements which a designer may have selected. Crack suppression membranes, substitution of porcelain and ceramic tile and the types of movement joints are examples of items which will impact suitability of individual installation elements.
3. Use Inspection Test Plans (ITP's) during construction to document the process and product implementation. ITP's help ensure that the correct methodology was followed, and no unauthorized product substitutions occurred. Proper documentation includes delivery dockets, photos of the installation process, and measurements of relevant elements.
4. Exercise caution when substituting products simply based on availability, as this carries a risk. Solely relying on ISO13007 *Ceramic Tile Grouts and Adhesives* [5] ratings to judge adhesive performance and suitability. Components with the same rating may not be equivalent or interchangeable across different manufacturers and individual installations. Consult relevant suppliers and installation system manufacturers before making significant changes to specifications. ISO13007 *Ceramic Tile Grouts and Adhesives* [5] ratings are not indicators of equivalent interchangeable products. Substituting tile adhesives should not be implemented without extensive consultation with the relevant suppliers of both the tile and installation system manufacturer. Site based engineers should be consulted to obtain a full and complete suite of information upon which to base the installation design upon.

REFERENCES

[1] So-Pro Pool installation Technical Guide 10th Edition.
[2] NAC Product Data Sheet-ECB 75 2020.
[3] Mapeguard 2 Product Data sheet, version Oct 10-2017.
[4] DIN 18535 Waterproofing of tanks and pools - Part 1: Requirements and principles for design and execution.2015
[5] International Standards Organisations ISO13007 Ceramic Tile Grouts and Adhesives.
[6] American National Standards Specifications for the Installation of Ceramic Tile A118-12 Crack Isolation Membranes for Thin-Set Ceramic Tile Dimension Stone Installation.
[7] BS EN 14617-12:2012-Agglomeratted Stone-Test methods, Part 12 Determination of dimensional stability.

Specific details of items within this paper are withheld to prevent association with specific location and construction failures. This paper is not suitable for use as a project specific interpretive guide or assessment of any similar projects that may bear resemblance to the issues outlined within it. This paper is not to be relied upon to support legal proceedings relating to similar construction works or as a record of any specific previous works.