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Cycles of Structural Intervention in Historic Buildings

Cycles d'interventions structurales dans les bâtiments historiques

Zyklus von Eingriffen ins Tragwerk historischer Gebäude

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SUMMARY

This presentation looks at a model for estimating the frequency of structural interventions in historic buildings based on the life expectancy of various building components. Experience with historic buildings is compared to related experience with historic bridges.

RÉSUMÉ

Cet article traite d'un modèle pour estimer la fréquence d'interventions structurales dans les bâtiments historiques, basé sur la durée de vie en service de divers composants. Les bâtiments historiques sont comparés aux ponts historiques.

ZUSAMMENFASSUNG

Der Artikel beschreibt ein Modell, welches in Abhängigkeit von der Dauerhaftigkeit der verschiedenen Gebäudekomponenten die Häufigkeit struktureller Eingriffe in historischen Gebäuden abschätzt. Die gewonnenen Erkenntnisse über historische Gebäude werden mit ähnlichen Erfahrungen verglichen, die an historischen Brücken gemacht wurden.

1. INTRODUCTION

The structure and fabric of historic buildings are inseparable. Most of our older historic buildings have load bearing exteriors wherein the architectural expression is also the supporting structure.

The most common agent of deterioration, either direct or indirect, is water. Northern climates accelerate the destructive influence of water through numerous freeze-thaw cycles during a typical year.

During the course of our work with historic buildings, we have noted a pattern of recurring repairs of a similar type in buildings of the same age.

This paper proposes a preliminary method to estimate the frequency of these *cycles of structural intervention.*

2. CONCEPT

The following major factors have been identified as impacting on the service life of historic buildings.

2.1 Service Life of Critical Building Envelope Components (F_{be})

This factor could be called the starting point for the proposed equation. This sets the units (years) for the result, F_i , of the equation. The building envelope (roof , exterior walls , deck waterproofing) is the first line of defense against deterioration of building structures due to atmospheric factors.

The service life of building envelope systems is supposedly indeterminate in historic buildings, if the buildings are to be preserved.

This is fine at the systemic level. However, we must now explore the impact at the component level.

Table 1 illustrates the typical service life for these components in the mid-latitudes of North America.

2.2 Environment (F_{en})

The environmental factor is a non-dimensional multiplier. The influences are numerous and the subject of many papers . In a northern climate there can be many variables. See Weaver [1].

Acid rain pollution is widespread in industrialized areas. Freeze-thaw cycling is very important and can vary widely at a given latitude.

System	Component	Service Life
Roofs	Asphalt shingles	20 years
	Slate shingles	30 years
	Built-up roof	25 years
Masonry Walls	Pointing	20 years
	Sealants	20 years
	Metal ties and supports:	
	Plain steel	10 years
	Painted steel	20 years
	Galvanized steel	30 years
	Stainless steel	indefinite

TABLE 1: Typical Service Life of Building Envelope Components

A maritime environment can also impact on the durability of structures. Seasalt, borne by rain and snow, will infiltrate the building fabric on which it falls.

Climate may also require the use of de-icing chemicals in large quantities. These enter the structure of the building with disastrous results.

Water is the most prevalent agent of deterioration in buildings. Obviously the amount of precipitation at a site impacts directly on this influence. The humidity levels determine the amount of organic growth, another important agent of deterioration for woods and masonry.

Typical values for the environmental multipliers could range from 0.50 for maritime exposure to 1.25 for a cold, dry climate.

If a site is subjected to more than one factor , only the worst case factor would be applied.

Internal environmental factors also impacts the life of the structure. The presence of termites, and high humidity levels which promote fungal growth, are particularly damaging to wooden structures.

2.3 Type of Structure (F_{st})

If a particular type of structure is known to perform poorly in a given environment, then the appropriate multiplier would be applied.

An example would be concrete structures which, when subjected to high numbers of freeze-thaw cycles, carbonation [2] and de-icing salt [3], are particularly susceptible to deterioration of both the concrete and reinforcement.

Values for this factor might range from 0.8 to 1.2 . This range is rather low due to the overlap with the environmental factor.

2.4 Success of Previous Interventions (F_{pr})

The success or failure of previous interventions will impact directly on the period of time before the next major repair is required. A typical case is the repointing of masonry joints. Many repointing campaigns of historic masonry structures have been undertaken in our area without regard to conservation principles. This has caused the intervention cycle to be reduced to 3 to 5 years.

Thus this multiplier might be as low as 0.25.

2.5 Maintenance (F_m)

Maintenance is a very important factor in determining the frequency of major repairs. Buildings under the care of state agencies are typically well cared for and are properly funded. The non-dimensional multiplier in this case could be as high as 2.0

On the other hand historic monuments under the care of volunteer groups, such as churches , do not benefit from professional care and often suffer from inadequate funding. Here the multiplier could be as low as 0.75.

2.6 Socio-economic Factors (F_{se})

The socio-economic factor takes into account the reaction time or delay period in obtaining funding and approvals for major repairs. The state of the economy, the political will, and the heritage status of the site can impact on this. A value of 5 years is recommended as a starting point.

2.7 Heritage Status (F_{hs})

The heritage status of a project affects the success or failure of subsequent interventions. Attar [4] provides a model for assessing the impact of durability versus the authenticity of the intervention.

A defective detail in the original structure may contribute materially to deterioration. However, this detailing may be essential to the heritage character. Maintaining this detail will increase the frequency of repairs. A typical value might be 0.9 for this situation.

The multiplication and addition of these factors yields the estimated frequency , F_i , (in years) of major structural interventions.

$$F_i = F_{be} (F_{en} * F_{st} * F_{pr} * F_m * F_{hs}) + F_{se}$$

3. DATABASE RESEARCH

The formal protection and conservation of historic buildings in Canada has only taken place in the last 20 years. Recording , monitoring and management of these resources is now well documented. Unfortunately, the time frame of 20 years is too narrow to allow statistical confirmation of the proposed factors.

Correspondence with Monumentenwacht Nederland confirmed a similar situation in Holland.

Research of a heritage bridge register will be discussed in the next section and was more fruitful.

The deterioration and repair history of civil engineering structures , such as canals, locks and dams, would be very relevant to this study. These structures are normally owned and maintained by state agencies and are well documented. Research into these types of structures unfortunately must wait for the next paper.

With the emergence of Facilities Management as a new discipline, substantial statistical data will become available to future generations.

4. SAMPLE PROJECTS

In the absence of hard statistical data, one must form an opinion based on observations from daily practice.

We are involved in a number of structures dating from the first era of major development in North America. These structures are now approximately 120 years old and many require major repairs.

Experience on these structures indicates that a minor structural intervention is required every thirty (30) years and a major intervention is required every sixty (60) years. Maintenance appears to be the major determining factor.

A recent project involved the evaluation of two (2) masonry (1860) and concrete (1900) fortifications. The environment is maritime and the concrete structures suffer from the use of seasalt contaminated aggregates. The structural intervention cycle for optimal management of these resources appears to be 15 years.

5. HERITAGE BRIDGES

The Province of Ontario, Canada , currently maintains a register of 85 heritage bridges. The majority are owned and maintained by local municipalities, under the scrutiny of the Ministries of Transportation and Culture and Communications of Ontario. See Reel [5].

Our research looked at the files of 9 of these bridges. The results are presented in Table 2.

Site	Bridge/Location	Built	Type	Maintenance History
3-96	Bank Street, Ottawa	1912	R/C arch	1916 - gunite repairs 1926 - deck waterproofing 1933/34 - gunite repairs 1936-38 - surface repairs 1941/44/45 - surface repairs 1956 - spandrel repairs 1960 - major rehabilitation 1975 - joint repairs 1992 - major rehabilitation
37-1038	Joe Kelley's, Newmarket	1925	Steel pony truss	1985- new deck and stringers recommended
26-79	Inverlea, Peterborough	1910	R/C arch	1967 - major rehabilitation 1985 - major repairs recommended
26-78	Hunter Street , Peterborough	1919	R/C arch	1990 - major rehabilitation
25-251	Church Street, St. Marys	1864	Stone arch	1979 - major restoration
9-2	Caledonia	1928	R/C bowstring	1983 - major rehabilitation
15-14	Pakenham	1901	Stone arch	1967 - masonry repairs 1974 - deck and masonry repairs 1984 - major restoration
19-262	Blackfriars, London	1875	W.I. bowstring wood deck	1950 - major rehabilitation, deck replaced 1964 - minor repairs 1974 - minor repairs 1983 - steel frame repairs 1986 - deck replaced, masonry 1990 - sidewalk repairs
16-47	Lyndhurst	1856	Stone arch	1986 - restored

TABLE 2: Maintenance history of selected Ontario bridges.

As can be seen , only recent maintenance repair history was available for most bridges. However, those that did have complete maintenance histories were very informative.

Sites # 3-96 and # 19-262 had the most complete maintenance histories. These tended to indicate an intervention cycle of approximately 10 years for historic bridges.

It is interesting to note that the early bridge builders in North America placed a building envelope over their wooden bridges. Many of these picturesque "covered bridges" are still in use.

6. THE PAST AND THE FUTURE

As time goes on , the list of historic structures expands. The federal government of Canada assesses the heritage status of all structures over 40 years old.

This threshold is now bringing the Modern era of architecture and sophisticated precast and post-tensioned structures under the purview of conservation regulation. This will create new challenges for the conservation community. We are already observing service life durations of only 20 years in entire **systems** in these contemporary structures, whereas the typical **component** service life in traditional construction often exceeds this number.

7. CONCLUSION

This paper proposes an equation for estimating the frequency of major repairs to the structure of historic buildings. In the absence of sufficient statistical and scientific data, the equation is proposed as a guide for use by heritage resource managers in prioritizing repairs to these structures.

As this process is confirmed and refined, a similar process may evolve that will allow the estimation of the cost of such interventions

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