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Post-disaster Resource Availability following a Wellington Earthquake: Aggregates, Concrete and Cement

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Abstract

The increased occurrence of natural disasters over the years have led to greater awareness of their impacts and the need to be prepared. New Zealand has encountered tsunamis, earthquakes and recent floods. Because of its geographical location, New Zealand is vulnerable to environmental risks. Disaster preparedness has become a focus in New Zealand and within disaster preparedness is post-disaster reconstruction planning. This paper evaluates the availability of resources for post-disaster reconstruction of the Wellington State Highway, with a focus on aggregates, cement and concrete. A benchmark of the resources required for reinstatement of the state highways was established using a resource estimation method. The results indicated that post-disaster reconstruction of the Wellington state highway is likely to be constrained by the limitations on construction resources in New Zealand such as aggregates, cement and concrete. This paper shows what alternative arrangements can be made given any shortages of these resources in a post-disaster environment.

Keywords: Earthquake, Reconstruction, Wellington, Resources

Introduction

Post-disaster reconstruction represents a primary issue for disaster preparedness. The important question is whether New Zealand's construction industry can return the damaged infrastructure to a previous, or better, state. The constraints of the construction boom currently experienced in New Zealand have led to several considerations of the implication of inadequate resources on disaster reconstruction. Successful reconstruction will ultimately depend on the level of resources available to execute the necessary activities, with the availability of finances as important as materials, plant and labour. Availability of resources is also governed by the policies and strategies put in place by the authorities to deal with the reconstruction phase.

Reconstruction Resource Planning in New Zealand

Geological and seismological data have shown occurrences of major earthquakes in several areas including Wellington, Hawke's Bay and Canterbury (Page, 2003). Statistically, the Wellington fault earthquake has a high probability of occurrence: 20 -25% in the next fifty years (White, 1997); but more importantly, due to its relatively high population density and large infrastructure, the impact of an earthquake on the city is likely to be unparalleled with any other disaster in New Zealand. The Wellington Fault last ruptured between 300 and 500 years ago, resulting in an earthquake having a magnitude of approximately 7.6 on the Richter Scale. This fault has produced large earthquakes, with a return period of 500 to 700 years. The Wairarapa Fault last major rupture was in 1855, generating an earthquake of magnitude of about 8.2 on the Richter Scale (GNS 2006). This fault has a recurrence interval of 1150 –1200 years (GNS 2006). The Ohariu Fault has a recurrence interval of 1500 – 5000 years and was last ruptured about 1100–1200 years ago (GNS 2006). Similarly, the Wairau Fault last ruptured more than 800 years ago and has a recurrence interval of 1000 –2300 years (GNS 2006); while the Shepherds Gully Fault last ruptured about 1200 years ago and has a recurrence interval of 2500–5000 years. Compared to other faults in the Wellington region, the Wellington Fault has the greatest probability of rupturing (GNS 2006).

According to White (1997), a "Wellington-based" earthquake of this nature (7-8 on the Richter Scale) would prove to be a realistic baseline for disaster planning. A 20 to 25 percent probability exist for a major earthquake, with an intensity ranging between 7 and 8 on the Richter scale, occurring with in the next fifty (50) years along the Wellington fault (White, 1997). To further support this scenario, the Greater Wellington Regional Council has based their emergency management planning on "a large, shallow earthquake along the Wellington fault" with a magnitude of 7.4 (on the Richter Scale). A scenario based on this event was therefore conceptualized to establish a benchmark, for evaluating resource requirements and understanding the implications of such an earthquake on resource availability constraints.

The State Highway network forms the core of the transportation system in New Zealand and this is vulnerable to disasters. The importance of the Wellington State Highway network in a post-earthquake situation is encompassed in providing access for the recovery of other lifelines. Mobilising resources may be one impediment to recovery, as is getting resources into a disaster area. It will be important to quickly restore the state highways to allow access to the damaged areas. Identifying and planning for resource restrictions to reconstruction is a fundamental step to disaster preparedness.

New Zealand's Civil Defence Emergency Management Act (2002), states that all lifelines, including the roading network, should be able to function effectively during and after an emergency. To meet this demand, it is essential that the governing body of the road network have a comprehensive framework identifying, evaluating and managing risks to the network (Seville & Metcalfe, 2004).

Research conducted by Rotimi et al (2005) and Seville and Metcalfe (2005), all had a singular pronouncement with respect to resources in a post disaster situation, which reflected the likely incapacity of the construction industry. However, the term "resources" in these reports was seemingly used to describe human resources and skill needs, rather than the holistic view of other construction resources., such as materials, plant and equipment. In light of disaster preparedness it is essential that all level of resources be evaluated to ensure that they are available and accessible for an efficient and fast reconstruction process.

Gregory et al (1995) and Page (2003) presented similar studies, which looked holistically at the capability of the construction industry to undertake reconstruction with in all sectors. Gregory et al (1995) compiled works by Hopkins D. (1995) and Lanigan T. (1995). Hopkins undertook an assessment of resource requirements while Lanigan assessed resource availability by utilizing Hopkins work as a benchmark for resources required for reconstruction of Wellington. This study concluded that New Zealand's resources could adequately undertake reconstruction following a Wellington fault earthquake. (Page 2003), utilised three scenarios of possible earthquakes, with estimated damages based on works conducted by The Earthquake Commission. Page combined various base workloads to quantitatively assess the resource capability of the construction industry. The agglomeration of all sectors (housing, roading, bridging, water distribution etc.) in these projects effectively meant that the effects of existing policies and plans established by individual controlling authorities on resource mobilisation were generalised, even though each authority possesses individual plans for reconstruction. The changes in the construction industry since 1995 means that there has been need for renewal of information on resource availability.

Evaluating resource availability for reconstruction within individual sectors captures the individual authority's plans which gives an idea of the support systems (such as MOUs, contracts etc.) that will facilitate the recovery. This research provides an evaluation of resource availability within the roading sector, in this case the state high way network, encompassing the policies and plans of Transit NZ.

Aggregates

Mineral aggregates form one of the main components of the New Zealand road construction industry. Aggregates are used in large quantities for building construction and roads. Over 4,000 tonnes of aggregates can be used in the construction of one kilometre of standard highway pavement; while a new six lane motorway may require in excess of 20,000 tonnes for the same distance (www.aqa.org.nz).

New Zealand is well endowed with a variety of materials through which aggregates can be processed, including river gravels, glacial moraine deposits, volcanic ejects and hard igneous and sedimentary rocks. Existing rock types in New Zealand are categorized into three main types: acid to basic volcanic rocks, metamorphosed "greywacke"; and sedimentary and chemically bound limestone. Currently, there are in excess of 600 aggregate-mining operations throughout New Zealand (excluding other minerals such as clays, pumice and limestone). Traditionally, the quarry industry has been described as a heavy industry, with high capital investment requirements and running costs. Issues of land ownership, environmental considerations and physical restrictions on the size and quality of the deposit imposed by the Resource Management Act, imposes difficulties in its procurement (www.aqa.org.nz). Transport costs are a major factor in the economics of supply due to the low value per tonne, and resulted in sources required to be close to its demand (Statistics NZ, 2000). As aggregate become depleted within a specific geographic location, manufacturers have been pressured to move further out of the market zone which has led to significant increases in transportation costs (www.aqa.org.nz).

Aggregates specifications required by Transit New Zealand for state highway construction are documented in TNZ M4 for base course and TNZ M6 (2001) for sealing chips. The most important rock types for high quality aggregate are greywacke sandston e, greywacke gravels, basalt and andesite (Christie T. et al, 2001). Geographical areas lacking in such rocks, commonly utilise limestone or other rock types. The specifications currently being used by the roading authority generally do not identify a part icular type of rock for aggregate, but rather specifies the required engineering properties of the materials (TNZ M/4). From the perspective of sustainable reconstruction, alternative aggregate supply should be in accordance with TNZ M/4 specifications.

In New Zealand, the quantity of quality rock available varies from region to region and in some instances such as Auckland, there is significant difficulties accessing local supplies, due to mineral exhaustion within the existing quarries (Christie T. et al, 2001). There are no detailed stock estimates of aggregates in New Zealand but it is generally perceived that there are extensive deposits of greywacke and volcanic rocks to meet future demands (Statistics NZ, 2000). Construction and maintenance of roads i s the major consumer of all aggregates produced in New Zealand, followed by the building industry (Statistics NZ, 2000). A small number of major companies supply most of the aggregates produced in New Zealand; but many smaller operators also contribut e to the country's supply (Christie T. et al, 2001). The major quarries in Wellington are Dry Creek, Belmont, Horokiwi and Kiwi Point, even though at present there has been considerable dependence on quarries at Plimmerton and Waikanae on the west coast of the Wellington Region. Closure of the Owhiro Bay quarry, a major source of aggregate on the south coast in the 1990's, has resulted in additional burden on the existing quarries. Projections indicate that these quarries will be unable to meet the demands in th e near future (Christie T. et al, 2001). Good quality, low cost greywacke aggregate is available from the alluvia gravel, forming the present -day floodplains and adjacent river terraces mainly from the Wanganui, Whangaehu and Turakina rivers; and high grad e aggregates is accessible from the Rangitikei River (Christie T. et al, 2001).The average production from the Wellington quarries is 800,000 tonnes per annum. Comparison of these statistics to the resource requirements for reconstruction will provide a go od indication on whether aggregate availability will be affected by production.

Cement and concrete

Concrete finds extensive use within the construction industry and forms a primary construction material for many existing structures along the state high way network. In-situ concrete is the traditional form of concrete construction and until the early part of the 20th century, formed the main method in construction (Ccanz, 2005). In-situ (concrete) placing on construction sites has been substantially reduc ed by developments within the pre-casting industry (Ccanz, 2005). The New Zealand industry has a well developed pre-cast concrete construction industry (Ccanz, 2005). Good supplies of the raw materials and technology in most parts of the country, has made the practice economical and practical. The emergence of concrete pre-casting techniques in New Zealand has allowed reinforced concrete to compete favorably with other forms of construction. Surprisingly, it has taken quite some time for this technique to i mpact on the residential construction market; with this renaissance occurring only in the past decade (Ccanz, 2005). The main advantage of pre-casting, whether done in factory conditions or on site, is that it offers the opportunity to control the quality to a high standard. The cement industry is primarily focused on the domestic market, with particular dependence on activities within the construction sector. The industry is supported by two manufacturing plants operated by

Golden Bay Cement and Milburn New Zealand Limited. Golden Bay Cement Company Limited, a part of the concrete division within Fletcher Building, along with Firth Industries Limited, Winstone Aggregate Limited and Hume Industries Limited. Milburn New Zealand Limited, a subsidiary organisation of the Holderbank group and "cornerstone" of the Milburn Group of Companies (Lyday, 2001).

Golden Bay Cement is New Zealand's largest cement manufacturer and supplier, with an estimated production of approximately 490,000 tonnes of cement per annum (Christie T. et al, 2000). The company's main manufacturing operation is concentrated at Portland, 8km south of Whangarei. Distribution (of the final cement product) is executed via Golden Bay's eight (8) customer service centers, strategically located around New Zealand. Twenty percent (20%) of Golden Bay's output is exported, primarily to Pacific Island nations (P.A. Consulting Group, 2001).

Milburn operates out of Cape Foulwind, near Westport and has grown steadily over the years, currently producing approximately 470,000 tonnes per annum (Lyday, 2001). To add value to its core cement business, the organisation has vertically integrated its operations to include (P.A. Consulting Group, 2001):

- Aggregates: A variety of aggregates is supplied in the Wellington Region, Hawkes Bay and in Auckland, primarily for markets of ready mixed concrete and roading;
- Concrete: A fleet of 34 ready mixed concrete plants owned by subsidiaries Ready Mixed Concrete and Allied Milburn, captures a great portion of the concrete market in New Zealand; and
- Lime: Agricultural and industrial lime is produced through Taylor's Lime in the South Island and Mc Donald's lime in the north.

Added to the economic benefits of this alignment, Milburn also supplies small quantities of cement to the Pacific Islands.

Average annual production of cement is approximately *1,040,000* tonnes, with consumption of *910,000* tonnes per annum (P.A. Consulting Group, 2001). These statistics give a good comparison (production versus consumption) of the limited capacity of the cement manufacturing industry to further increases in demand. Cement supply may thus be vulnerable in this regards, during post-disaster reconstruction, depending on its requirements.

Research Methodology

Workshops formed the initial part of field work in this research. They were specifically used in association with the literature to understand current systems associated with New Zealand's state highway network and disaster management. The workshops provided a good means of meeting first hand with potential participants and deciding on which organisations to approach for interviews. These introductions (of the research to potential participants) were much more formal and effective, compared to the introductions via telephone.

A realistic disaster scenario was used in the research. This was primarily due to:

(1) The resource requirements approach which involved a quantity "take-off" of damaged infrastructure could easily be validated from the scenario; and

(2) It provided a medium to model the necessary physical constraints (such as transportation) which are likely to affect resource availability;

Interviewing various people within the industry was the main investigatory tool used in the research. With the research consisting of a disaster scenario, it was advantageous to have "face to face" dialogue with participants, rather than to use structured questionnaires. These interviews also allowed greater details and follow-up questions to be administered, which were instrumental in understanding various disaster policies and problems of resources currently encountered within organisations.

The objectives of the research meant that it was essential to ascertain related views on resource availability and disaster management from people within the roading sector. Obtaining statistical data was not the main aim of the interviews; rather they were meant to capture the policies, opinions and issues on resources within various categories of organisations (controlling authority, contractors, consultants, disaster management groups etc.) that would be involved in reconstruction. The various roles of these organisations also meant that different questionnaires had to be prepared. Questions were derived based on the implications of the scenario; issues arising from the literature review and views expressed at the workshops. They were structured to determine which resources were currently engaged with difficulties in meeting existing demand. The questionnaires were amended accordingly as additional issues to post-disaster reconstruction emerged during the initial interviews.

The organisations selected were those identified within the roading industry with interests in disaster management. The study was based on the state highway network which meant that Transit New Zealand was an automatic choice. Other controlling authorities including the Wellington CDEM were selected based on there potential influence on reconstruction. Contractors and consultants form the main players of the construction industry and formed an integral part of the interviews. Larger/national organisations within each sector were selected, since it was logical that if these organisations had difficulties mobilising resources, then smaller organisations were unlikely to do any better. In addition, the larger organisations were likely to be the main contractors in post-disaster reconstruction. The workshops were instrumental in identifying the people and companies in New Zealand of most use for the research.

Individual selections to participate in the research were left to the organisation to provide the best person to answer the questions. The participants which were presented by the organisation were either from upper and middle management or senior engineers.

The estimate of resources for post-disaster reconstruction was essential in comparing current resource levels to what will be required for the reinstatement of the Wellington State Highways.

The comprehensive work to date (in New Zealand) with regards to estimating the resources required for reinstatement of Wellington City after a disaster, is by *Hopkins,* as detailed in *Gregory et al (1995).* The main reasons for re-estimating the resource requirements were based on:

(1) Substantial growth in the infrastructure (since the previous estimates in 1995) meant that there was need to update this information;

(2) The previous approach grouped all categories of roads (both rural and state highways), which made it difficult to extract the state highway reconstruction resource requirements (which is the main aspect of this research); and

(3) The method used previously was highly empirical and used a top -down estimating approach. The estimated (final) reconstruction costs were first determined, followed by the determination of activity costs by applying various factors. Each activity costs were then systematically broken down into resources by applying ratios of plant, material and labour.

The method derived in this research adopt ed a standard quantity "take -off" approach. Contrary to *Hopkins* me thod, this method estimated the material requirements for various aspects of state highway reinstatement, from which labour and plant requirements could be determined.

Participants were solicited from four categories of organisations associated with eithe r the construction industry or disaster management teams/groups in New Zealand. Fifteen participants were interviewed, which provided a good baseline to determine what were the main resource constraints and issues facing the industry. The majority of the t arget organisations and the participants were located in Wellington, Ne w Zealand. These participants could therefore easily relate to the scenario, geography and effects associated with a major disaster in the area. All prior arrangements for the interview s were made via telephone and emailing.

A quantity take-off approach was used to estimate the resource likely to be required to reconstruct damaged sections of the Wellington state highways following a major earthquake. Vulnerabl e sections of the pavement, bridge overpasses and other ancillary structures within the disaster zone needed to be quantified before the resources required for reinstatement could be determined. The difficulty however, was realistically determining the extent of damage that the stru ctures would be subjected to. With the emphasis of this report on resource availability, a viable method of establishing the resources required for reconstruction was required. The damage assessment therefore combined two processes:

(1) predicting the extent of damages likely to be incurred on the State Highways 1,2, 53 and 58 based on the hazard maps.
(2) bridge (and other structure) replacement estimation was based on identifying the vulnerable bridges and then estimating the resources that would be requi red for replacement.

The interviews, which represented eleven organisations, presented a comparatively large set of data for analysis. The different roles of the organisations and different questionnaires meant that the analysis looked at themes across th e responses, rather than trends. While comparisons of responses were done within each category and across categories, the primary aim was to identify the resource difficulties within the client (Transit NZ), consultants and contractors associated with the state highway network.

Availability Of Construction Materials

Reconstruction activities following a Wellington fault earthquake will commence at the initial point of response and curtail in the final stages of long term recovery, which based on the inter views can take as much as 3 to 5 years. The greatest diffi culties of mobilising resources (resource availability) will be at the initial stage but can be expected to normalise as time elapses.

Proper scheduling of resource utilisation and pre-planning plays an important part in ensuring that resources are available.

An amalgamation of responses to the interviews across all categories, on the aspect of shortages in materials within the industry, revealed that *aggregate, cement and concrete,* were ranked amongst the greatest threat to post-disaster reconstruction. Similarly these materials were identified at the workshops and conferences, as imposing difficulties in procurement, which indicated a level of consistency within the construction industry.

Material	Specific Product Line	Perceived Vulnerability
Aggregate	Roading and concrete	Depleted supply in Wellington may warrant importation from other regions.
		Aggregate quarries likely to be subjected to damages.
Cement and Concrete	Cement	Supply difficulties, possible related to local production.
	Precast components	- Limited suppliers. - Long lead times for special members.

Table 1: Summary of commentary on material vulnerability.

Aggregate Availability

Based on the interviews, the main issues likely to inhibit availability of aggregates for state highway reconstruction following a Wellington fault earthquake are: limited production and damages to quarries and transportation. The issue of production identified by the participants supports the growing trend in aggregate supply in Wellington Region. The closure of the Owhiro Bay quarry has resulted in considerable dependence on quarries at Plimmerton and Waikanae on the west coast of the Wellington Region with shortages predicted in the region. These effects are likely to coincide with the relatively high demand of reconstruction. Looking at the estimated aggregate requirements for reinstatement with average regional (Wellington) and national figures of production gives a good indication of what can be expected:

Total Aggregate Requirements (tonnes)	***Wellington Region Quarry Production (tonnes/annum)***	***National Production of Aggregate (tonnes/annum)***
570,698	800,000	21×10^9

Table 2: Comparison of aggregate requirements to average production.

Based on these figures, the quarries in Wellington will be severely challenged to meet the demands of state highway reconstruction within the area. If the requirements of Transit

NZ (or government priority) are to have the State Highway network fully operational within a timeframe as much as six months, it is perceivable that aggregate availability will be inadequate.

There is also likely to be competition from other sectors, which will independently be involved in similar reconstruction activi ties. It is clear that reconstruction will necessitate importation of aggregates to the Wellington area following an earthquake of this magnitude. Competition by contracted parties for aggregates, including those associated with other lifelines and private reconstruction, is also likely to lead to costs inflation. The high level of competition envisaged in a post -disaster scenario has led to Transit's inclusion of MOUs with major aggregate suppliers as part of their emergency response plan with the aim of alleviating any such supply issues from the regional (Wellington) market. From a national perspective, aggregate production is likely to substantially outstrip aggregate requirements which suggests that aggregate supply would not require offshore importation.

Notwithstanding limited production, depleting quarries in Wellington and the possibility of high competition for the resource, there is very good possibility that a Wellington fault earthquake may affect operation s at the major quarrying areas. The maj or quarrying areas are located on the up -thrown side of the Wellington fault and operations are likely to be significantly disrupted. Superimposing the expected (earthquake) intensities on the quarrying areas shows that the quarries lie within significant damage zones of intensities MM IX and VII.

Damages to the aggregate crushing plant do not imply a closure of operation; mobile crushing plants are common in New Zealand and could be mobilised at these quarries. The main issues however that are likely to a ffect aggregate supply are based on this scenario are:

- the quarries' road network may experience significant damage due to heavy shaking associated with *MM IX* intensities, which can have long term implications; and
- the possibility of a drop in the land, a reversal in the 6m rise that occurred in the 1855 Wairarapa fault earthqu ake, is likely to not only devastate the existing network built on this section but also, devoid areas of aggregates.

If these damages were incurred, then alternative sou rces will have to be considered particularly in the initial stag es of the reconstruction period while the se Wellington suppliers recover. Several alternatives for road base aggregates may exi st in a post disaster situation which should not only be considered from a sup ply situation but also from the perspective of maintaining quality control. Greywacke and other volcanic rocks is abundant in Northland but the cost of transporting aggregates thro ugh this distance even by water will be high. It may be preferable to utilis e aggregates from closer regions, such as Wanganui and Manawatu, which can supply substantial amounts of aggregates at relatively short distances. Of course, much further areas such as Canterbury exist, where Torlesse Supergroup Greywacke of the Southern A lps can provide large, easily mined supplies. There are other alternatives of recycled materials, most notably recycled concrete which is likely to be in good supply with as many as 60,000 property damages anticipated. Essentially, these materials are like ly to become available as refuse in the aftermath of an earthquake and therefore can be adequately disposed through recycling.

Transportation is the obvious impediment to sourcing aggregates due to the physical barriers that will be imposed by the earthquake. With damages to rail and the state highways, it ultimately means that the traditional means of moving aggregates becomes, for all practical purposes, impossible during the initial stages of reconstruction. The best alternative identified by several participants is the utilisation of barges which coincidentally has been regarded as a growing transportation mode for aggregates.

Cement and concrete availability

Cement and concrete availability is likely to be constrained by two associated trends in the industry:
(1) inadequate local production; and
(2) limited number of suppliers of pre-cast components coupled with long lead times.
The root of the production problem lies in the manufacturing industry which has its productivity geared to meet domestic demands. On average, the construction industry consumes 910,000 tonnes of cement per annum, from an annual production of 1,040,000 (P.A. Consulting Group, 2001). It shows that limited scope exists for increases in consumption, before supplies become critical. In the context of supply capacity for post-disaster recovery, the estimated quantity of cement required for state highway/bridge reinstatement - *1,986 tonnes*, is likely to prove beyond the local industry's capability. The recovery of the main structures would be done within the first year of reconstruction to ensure that the access bridges along the state highways are permanently reinstated. This means that most concrete works on the state highway is likely to be completed during this time, which reflects the importance of ensuring that cement requirements are adequately met during the initial period of state highway reconstruction. The current dependence on just-in-time inventory by contractors in New Zealand offers no assistance with cement mobilisation in a Wellington quake scenario since there are unlikely to be any major stockpiles available. However, whether supply of cement becomes a major impediment will depend on two factors:

(1) Prioritisation of construction works versus post-disaster works; if damaged infrastructure is valued greater than developmental works post-disaster works would have first preference to cement.

(2) The ability of the major suppliers to collaborate with their overseas counterparts for supply assistance. Milburn in particular, as a subsidiary company of the Holcium Limited (one of the largest cement-manufacturing groups in the world), are in the position to ascertain the necessary assistance. However, importation of cement will have additional costs attached and longer lead times for shipping.

In addition to these possibilities for improving cement availability (post-disaster), there is the alternative of reducing exportation to the Pacific Island, which is indeed of small quantities (based on average local production and consumption figures) from Golden Bay.
Apart from the limitation of cement production, procurement of pre-cast units was identified the participants as possible sources of difficulties in procurement post-disaster. Component pre-casting which involves manufacturing various concrete components, such as pipes, bridge lengths, columns and site barriers, generally requires considerably more engineering input than other concrete works. Based on current trends, participants indicated that fluctuations in supply currently exist in the market for these pre-cast

components, along product lines such as culverts, piles and slabs. The root of the supply problem has been the increasing demand of pre-casting, coupled with the supply limitations. This increased demand may also account for the lead time problems identified by contractors. Based on the interviews two important procedures which could be adopted based on current successes in alleviating materials problems (and more specifically pre-casting) are:

(1) It maybe imperative to have the involvement of national contractors (possible Transit's network contractor) in post-disaster re-design, to ensure that available products (post-disaster) are utilised, as opposed to traditionally used pre-cast components. This method is also consistent with internationally experiences.

(2) *Ad hoc* decisions on lengthy lead times for procuring of pre-cast components may warrant amendments to design specifications to accommodate changes in material. Such requires flexibility in the project team.

From a logistical perspective, it will be necessary for the road network to be substantially accessible before cement and concrete components can be effectively transported. Structural pre-cast concrete members in particular are effectively transported in New Zealand by articulated trucks. The road network will also facilitate ready mix concrete for in-situ works on joints and other construction, which requires the use of mixing trucks.

Conclusion

Evidence suggest that aggregate production at a (Wellington) regional level is likely to be insufficient and even worsened by damages to the main quarrying areas which are located in proximity to the Wellington fault. However, from a national production perspective, aggregate requirements are unlikely to overwhelm production. Importation of aggregates from areas such as Wanganui or Christchurch by barges forms the best alternative from a planning perspective, with expected damages to the rail, state highway and Wellington harbour.

The manufacturing industry for cement and cement products in New Zealand depend heavily on simply meeting local demands; only small quantities are exported and there are limited product lines. Cement and pre-cast components are all at risks, due to issues associated with limited production and product line and subsequent extended lead times for importation. “Just-in-time” delivery model which is the nature of the current supply chain will be faced with surmountable issues associated with intense competition from various sectors and poor transportation conditions into Wellington following the earthquake. Very few alternatives exist due to the nature of these problems. Importation remains the only viable option of meeting the demand of post-disaster reconstruction even though a reduction in current export levels of some of these products following the disaster could also assist in mobilising resources. Most manufacturers have the necessary international connections to ensure that these products are adequately supplied but lead time constraints should be anticipated. To minimise the procurement difficulties associated with limited product line, it maybe necessary to ensure that designs are done with less reliance on these items and more confidence in what is available post-disaster.

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