ISRAEL BRIDGE INFRASTRUCTURE INVENTORY AND SEISMIC FRAGILITY ASSESSMENT

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Abstract

This paper presents the local results of the INFRA-NAT (Increased Resilience of Critical Infrastructure under Natural and Human-induced Hazards) research project carried out in the years 2018-2019, supported by the European Commission, aimed at bridge infrastructure vulnerability assessment in three project-participating countries: Italy, Northern Macedonia and Israel.

The INFRA-NAT project is a multi- phase project, carried out at each of the participating countries independently, while sharing and exchanging information and work procedures throughout the project. Main activities of the project at each participating country included: (a) assessing currently existing seismic hazard models and updating them, as needed, to create a recent state-of-the-art hazard model, (b) collecting and harmonizing full exposure databases (inventory of assets) featuring all relevant information on existing bridges, at three different levels of information, and (c) production of fragility curves for seismic behavior of typical bridges, to allow for characterization of direct physical vulnerability and indirect losses, as well as full road network analysis.

This paper focuses on the Israeli case study, showcasing the results of the three-tiered data collection phase, which included Level 0 GIS-based data collection, Level 1 data collection, including more specific information as per piers, abutments, deck, supports, etc, and Level 2 data collection, including detailed full information of bridges, based on bridge plans and blueprints, as well as site surveys. Following the data-collection phase, typical bridge types were identified, and relevant taxonomy groups were defined. For each taxonomy group, nonlinear time history analyses for an ensemble of locally fitted ground motions was carried out, based on which fragility curves were built, using state-of-the-art procedures. This, for the first time in Israel, allowed for the characterization of fragility curves relevant to Israeli typical bridges, which can be used to assess seismic vulnerability of bridge infrastructure on a national level (such as integration for use in the HAZUS platform and similar uses), which in turn can assist decision makers with prioritizing seismic preparedness actions.

Keywords: seismic analysis, fragility assessment, bridge structures.

1. Introduction

The State of Israel is located in a seismically active area, situated between the African and Arabian tectonic plates. The eastern border of the State of Israel aligns with the Dead-Sea transform (DST), which has the highest concentration of seismic focus points in the country. Both plates of the DST line are moving north, with the eastern side moving at a faster pace than the western side, resulting in a relative velocity of about 4 mm/year. The State of Israel is considered to be under seismic threat of an expected medium to strong earthquake (estimated at a Magnitude of 6.5-7.5) which, based on historical records and evidence, occurs, in average, every 80-100 years. Considering the fact that the last strong earthquake to occur within State borders dates back to 1927, statistically speaking, a strong earthquake may occur at any given time, meaning that in order to reduce future damage, mitigation and preparedness actions must be acceleration.

Various national programs to raise awareness and prepare for a seismic event are currently taking place in the State of Israel, mainly under the leadership and support of the National Seismic Preparedness Steering Committee (NSPSC) appointed by the Israeli Government in 1999. However, to date, models used for damage (both direct and indirect) estimation are outdated, and based on HAZUS fragility information that is not relevant to the local building and infrastructure stock.

Lack of fragility information relevant to local building and infrastructure stock, which will allow a more realistic damage assessment on a national level, as a basis for better decision making with regards to seismic preparedness, motivated participation in this European collaboration project of three countries- Italy, Macedonia and Israel. The project, INFRA-NAT (Increased Resilience of Critical Infrastructure under Natural and Human-induced Hazards), was supported by the European Commission, and was carried out in the years 2018-2019.

Main activities of the project, in each participating country, included: (a) assessing currently existing seismic hazard models and updating them, as needed, to create a recent state-of-the-art hazard model, (b) collecting and harmonizing full exposure databases (inventory of assets) featuring all the relevant information on existing bridges, at three different levels of information, and (c) production of fragility curves for seismic behavior of typical bridges, to allow for characterization of direct physical vulnerability and indirect losses, as well as full road network analysis. Other activities of the project included building a web-based platform (WBP), containing a database of collected bridge information, as well as the fragility curves produced, several training sessions for civil protection communities and practicing engineers, National, European, and International publications, a project website, and production of project events, to name a few.

This paper is focused on the Israeli case study, showcasing the results of the three-tiered data collection phase, which included Level 0 GIS-based data collection for approximately 2100 bridges (including basic information for bridge location and length), Level 1 data collection for approximately 100 bridges (including more specific information as per piers, abutments, deck, supports, etc, based on open/free web-based data sources), and Level 2 data collection for approximately 15 bridges (including detailed full information of bridges, based on bridge plans and blueprints collected, as well as site surveys to identify physical deterioration of bridge elements). Following the data-collection phase, typical bridge types were identified, and relevant taxonomy groups were defined. For each taxonomy group, nonlinear time history (NLTH) analyses, for an ensemble of locally fitted ground motions was carried out, based on which fragility curves were built, using state-of-the-art procedures. This, for the first time in Israel, allowed for the characterization of fragility curves relevant to Israeli typical bridges, which can be used to assess seismic vulnerability of bridge infrastructure on a national level (such as integration for use in the HAZUS platform and similar uses).

2. Data collection methodology

The first phase of the INFRA-NAT project included data collection in multiple levels, so as to create a database of bridge information, which will be open to the public (as part of a WBP), as well as to serve the analysis carried out during the second phase of the project. The data collection process was carried out remotely, using online open-sources. For some bridges, additional data was collected based on blueprints obtained, as well as field surveys.

The first and lean level of information collected (Level 0) included a GIS-based survey of open-source online repositories. This allowed collection of information regarding location and length of bridges within the country. The second level of information collected (Level 1) was also web-based, utilizing sources such as Google Street View, Wikipedia, govmap, Geological Map of Israel (1:50,000), and other internet searches. Data collected for these bridges was based on the short data collection form defined in INFRA-NAT project Deliverable D2.1 [1]. Information collected included: completion year, static scheme, number of lanes, number of spans, deck type, deck material, road width, span lengths, connection type, number of longitudinal girders, number of deck supports, presence/ absence of pier cap, pier material, pier typology, abutment typology, no. of columns, column heights, section types and sizes. The third level of information collected (Level 2) was based on blueprints obtained, as well as field surveys. Data collected for these bridges was based on the long data collection form defined in INFRA-NAT project Deliverable D2.1 [1]. Information in five sections of the form was gathered: main (general) information, deck information, pier information, abutment information, damage state. In addition, reinforcement and foundation information is also accounted for.

3. Fragility assessment and curve derivation

After the collection of data and preparation of full exposure databases (inventory of assets), featuring all relevant information on existing bridges, the bridges were classified into taxonomy groups, based on their characteristic properties. Taxonomy groups were identified and defined per participating country's relevant inventory, based on statistical analysis of the data collected in previous stages. This allowed grouping of bridges based on similar attributes, and estimation of fragility per taxonomy group, rather than per bridge. Fragility analysis per specific bridge (as opposed to per taxonomy group) is (a) costly and lengthy, and (b) does not allow to capture an entire range of behavior of bridges, so as to allow network and damage assessment on the global/ national level, which was one of the desired outputs of the INFRA-NAT project.

Bridges were thus grouped based on material, number of spans, static scheme, deck type, and pier type. In the case of the Israeli bridge stock, the following taxonomy groups were defined:

Material	spans	Static scheme	Deck type	Pier type
RC	1	Simply supported (SS)	Box (BO)	Single column (SC)
	2-3	Continuous (C)	Beam (B)	Multiple column (MC)
	4-5	Frame (F)	Slab (P)	Wall (W)
	6+		Other (O)	Other (O)

This allowed tagging taxonomy groups with names such as RC-4/5-C-BO-SC, RC-2/3-C-B-MC, etc. In total, 76 taxonomies were defined, based on data analysis of Level 1 information collected. Each of the Level 1 bridges was classified into one of the taxonomy groups defined. For each of the taxonomy groups identified for the Level 2 bridges, fragility assessment was carried out so as to develop its fragility parameters and curve. Properties used for nonlinear analysis, as part of the fragility assessment, were derived based on blueprints obtained for bridges within the taxonomy group, while using statistical information of other bridges within the same group (gathered from the database previously built), so as to create variations of bridge properties, to allow a more general and realistic fragility representation.

Fragility assessment was preformed using the BRI.T.N.E.Y platform developed by the Eucentre Foundation [2]. The tool creates finite element models (FEM) of bridges, on which NLTH analysis is carried out using OpenSees framework, and processes the numerical results to obtain fragility functions for each model analyzed. In order to use the platform, several assumptions were made. These include:

- Deck, beams and foundations were assumed to behave elastically under the seismic motion considered, and thus do not contribute to the bridge failure modes. This means that all fragility of the bridge is concentrated in the piers, which are able to yield, be damaged, or collapse.
- In the original BRI.T.N.E.Y platform, plastic hinging can only occur at the bottom of the pier. Later adjustments to the software developed allow yielding in the top end of the pier as well, so as to allow monolithic connection behavior to also be considered.
- Piers are assumed to be rigidly connected to bridge foundations, meaning that no soil-structure interaction was considered at this stage.
- BRI.T.N.E.Y tool does allow for foundation and abutment modelling assumptions to be considered in the analysis, but the lack of necessary data on the soil system did not allow exploiting these modeling capabilities. However, this was not considered a major issue for the purpose of the risk assessment of the bridge portfolios, since most design practices require that the foundations be capacity-protected, which typically leads to significant conservatism in the design of bridge foundations.
- Failure mode is based on 3 possible phenomena: (1) plastic rotation at pier, (2) shear failure at pier bottom, (3) unseating of deck/ beams at bearing level (involves the deck and the sub-structure). Fragility curve is built based on envelop of these failure modes. That is, the maximal fragility value of the 3 abovementioned phenomena determines the fragility parameters of the bridge.
- Fragility curves are created based on three limit states: not damaged (ND), damaged (SLD) and collapsed (SLC). Plastic rotation at pier and unseating of deck modes can develop one of the three abovementioned limit states, while shear failure at pier can only develop ND or SLC limit states.
- Structural deterioration interactions between elements leading to collapse was not specifically accounted for in the models (i.e. elements will deform beyond the limit response thresholds).
- Uncertainties in material parameters such as strength of concrete and rebar steel were taken into consideration through the beta values, as part of fragility assessment procedures. Furthermore, to account for uncertainty in the capacity thresholds for pier components, they were modelled as lognormal random variables that were sampled every time an analysis was conducted.
- Seismic hazard intensity levels considered correspond to 98, 224, 475, 975, 2475, 4975 and 9975 year return periods. Instead of using PGA for intensity, average acceleration in the time periods of 0.2-1.0 sec was considered.
- A set of 30 ground motions, fitted to relevant seismic scenarios expected in the State of Israel, and fitted to the abovementioned intensity levels, were used.

More detailed information on the platform, the analysis procedures used, and the assumptions made can be found in in INFRA-NAT project Deliverable D3.2 [3].

4. Results- data collection and bridge inventory data

4.1. Level 0 data

OpenStreetMaps, which is an open-source online repository that contains geographical information, including roads and infrastructure of different countries worldwide was used to obtain preliminary information as per the amount, and locations, and the lengths of the Israeli bridge inventory. A total of 2,089 bridges, with location as shown in Fig. 1, were identified. The amount of bridges per province was obtained by performing a spatial correlation of the bridges found and the province borders leading to the information depicted in **Error! Reference source not found.**2. Additionally, the bridge length information was extracted for each asset, and processed in a histogram to determine the length distribution within the inventory. This information revealed that 85% of the bridges are under 150 meters in overall length and that the median length category is between 50 and 150 meters.

4.2. Level 1 data

Level 1 information survey for Israel included a web-based data collection process for approximately 100 bridges out of the ~2100 Level 0 bridges, as shown in Fi. Data collected for these bridges was based on the short data collection form defined in [1]. While trying to fully confirm with the short data form created, some issues arose during Level 1 data collection. From data collected it was apparent that many estimations were needed in order to extract dimensions from photos. Usually, span length estimations added up to less than the given bridge length (derived from Level 0 information or from blueprints). Also, in many cases there were no visuals of the bridge that could be used in order to collect data (e.g. in peripheral locations where Google Street View is not available). In other cases, there was an excess of information collected. Sometimes the static scheme of a bridge changed along the same bridge, and the bridge could not be properly categorized.

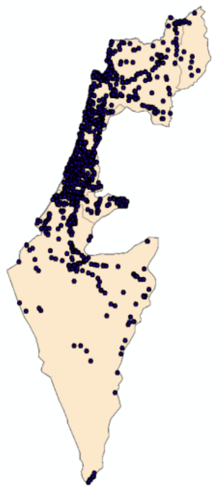


Fig. 1- Inventory of bridges in Israel detected with OpenStreetMap

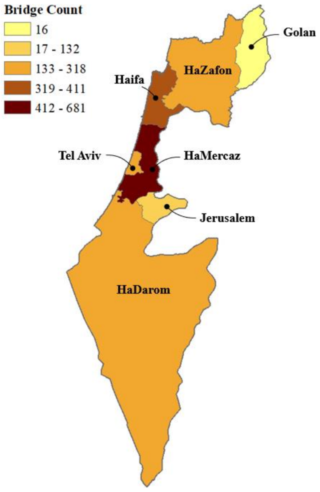


Fig. 2- Distribution and number of bridges per province for Israel

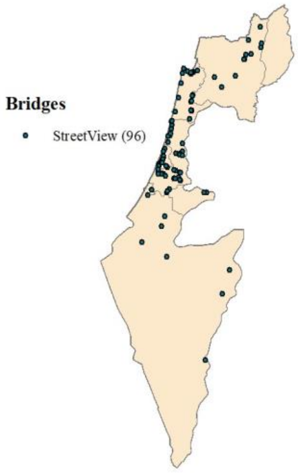


Fig. 3- Bridges with Level 1 information for the Israeli case study

4.2.1. Structural material

The majority of Israeli bridges, based on the information collected for the 99 Level 1 bridges, are constructed of reinforced concrete (RC), either pre/post tensioned, or regular RC, while a minority of bridges are constructed using steel and concrete, whereas a single bridge identified in the study was constructed of steel.

4.2.2. Static scheme

Bridges were classified into one of *thirteen* (including other) static schemes. As can be seen in Fig. 4, the majority of Israeli bridges, based on the information collected for the 99 Level 1 bridges, represent a girder-with either a continuous or simply supported static scheme.

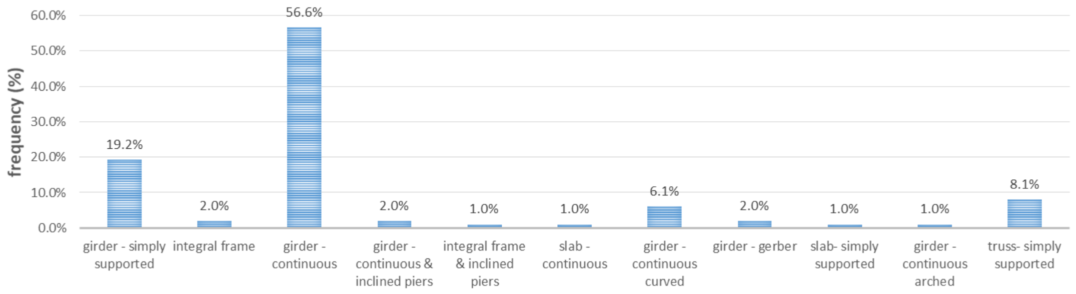


Fig. 4- Static scheme of bridges

4.2.3. Bridge length

The classification of bridges based on their total length is given in Fig. . As can be seen, the majority of bridges are up to 300 meters in length. It is noted that length was based on the Level 0 data provided, and it is disputable how accurate this information is with regards to calculated bridge length.

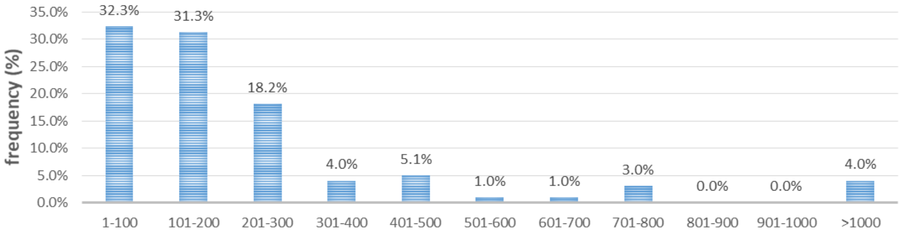


Fig. 5- Total bridge length

4.2.4. Deck type

Bridges were classified into one of *six* deck types. The majority of Israeli bridges, based on the information collected for the 99 Level 1 bridges, have a pre/post-stressed beam deck type. Another popular deck type in use is the box deck.

4.2.5. Number of spans

The classification of the 99 Level 1 bridges into span length categories show that the majority of Israeli bridges have 4-5 spans (36.4%), 27.3% have 2-3 spans, 12.1% of bridges have either 6-7 or over 10 spans, 9.1% of bridges have a single span, while 3% of bridges have 8-9 spans.

4.2.6. Connection type

Bridges were classified into one of *four* (including 'other') connection types between the deck and pier. The majority of Israeli bridges, based on the information collected for the 99 Level 1 bridges, are supported on bearings. Another popular design option is the monolithic connection between the deck and piers.

4.2.7. Pier typology and section type

Bridges were classified into one of *eight* (including 'other') pier typologies. The breakdown of typologies of the 99 Level 1 bridges can be seen in **Error! Reference source not found.**. Bridges were classified into one of *four* (including other) section types for the pier columns. The breakdown is given in **Error! Reference source not found.**

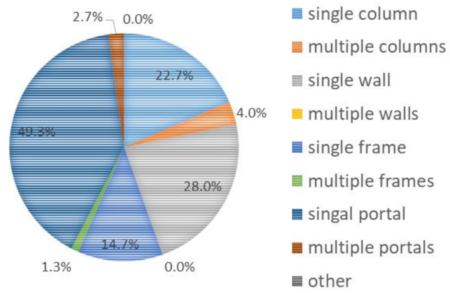


Fig. 6- Pier typology

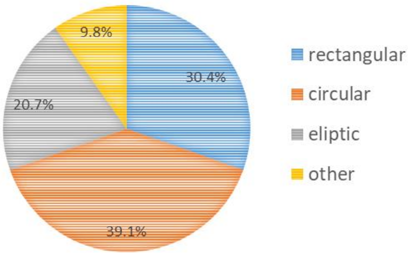


Fig. 7- Pier section type

4.3. Level 2 data

Site inspections were carried out in order to fully characterize representative bridges. This included collection of information that is not readily obtainable through desktop data collection sources. The inspections were recorded using the full data collection form produced for INFRA-NAT, as described in [1]. Based on Level 1 information collected for approx. 100 bridges, several representative bridge types/ schemes were selected, and detailed plans for 16 bridges were collected and analyzed, as a basis for Level 2 data collection.

4.3.1. Corrosion Damage

During the damage survey carried out onsite as part of Level 2 data collection, damage due to corrosion was investigated. For each of the 16 bridges analyzed, damage observations for the following were recorded: corrosion damage at deck surface near support, corrosion damage at deck surface near midspan, corrosion damage at deck beam near support, corrosion damage at deck beam near midspan, corrosion damage at gerber supports, corrosion damage at pier cap, corrosion damage at pier top portion, corrosion damage at pier lower portion, corrosion damage at base- foundation, corrosion damage at abutments, corrosion damage at parapets and corrosion damage at supports. Damage was classified into: not evident, mild, medium, serious or very serious. Damage due to corrosion was limited (7%) in comparison to the cases where no damage was observed (87%). Where corrosion damage was apparent, it was mostly found at abutments (36%), connections (14%), or deck surface near support (15%). Examples for corrosion damage found to bridge elements in Israel can be seen in Fig. 8.


(a) (b)

Fig. 8- Corrosion damage to bridge decks

4.3.2. Cracking damage

During the damage survey carried out onsite as part of Level 2 data collection, damage due to concrete cracking was investigated. For each of the 16 bridges analyzed, observations for the following were recorded: cracking at deck surface near support, cracking at deck surface near midspan, cracking at deck beam near support, cracking at deck beam near midspan, cracking at gerber supports, cracking at pier cap, cracking at pier top portion, cracking at pier lower portion, cracking at base- foundation, cracking at abutments, cracking at parapets, and cracking due to cyclic loading (fatigue). Cracking damage was classified into: not evident, very subtle, subtle, medium, wide, or very wide. Damage due to cracking was limited (7%) in comparison to the cases where no damage was observed (84%). Where cracking damage was apparent, it was mostly found at supports (38%), abutments (31%), or parapets (15%). Evidence for cracking of bridge elements can be found in Fig. 9.

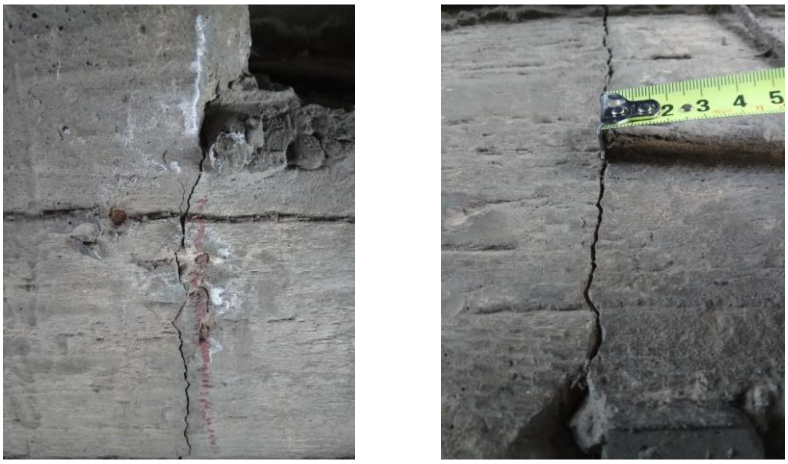


Fig. 9- Evidence of cracking of bridge elements

4.3.3. Damage - Concrete cover falling, delamination, erosion

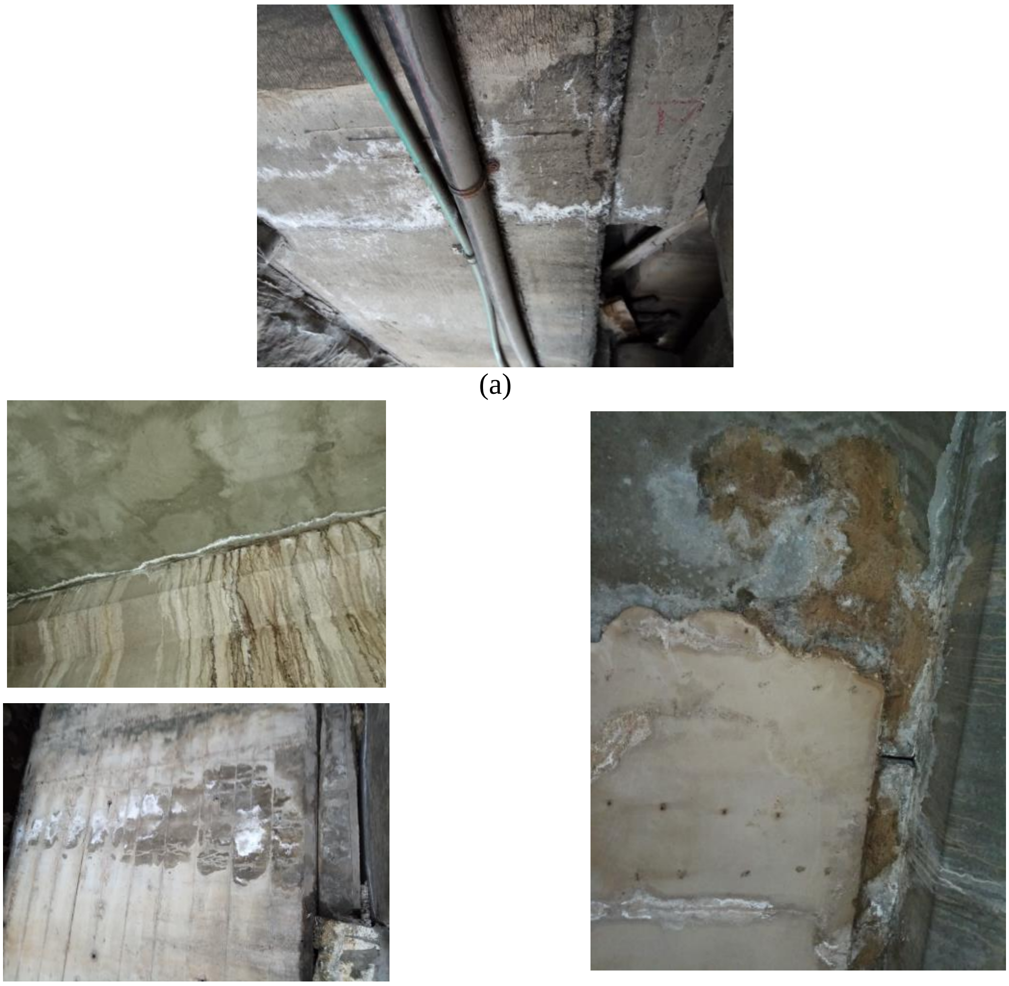
During the damage survey carried out onsite as part of Level 2 data collection, damage due to concrete cover falling, delamination and erosion was investigated. For each of the 16 bridges analyzed, observations for the following were recorded: damage at deck surface near support, damage at deck surface near midspan, damage at deck beam near support, damage at deck beam near midspan, damage at gerber supports, damage at pier cap, damage at pier top portion, damage at pier lower portion, damage at base- foundation, damage at abutments, and damage at parapets. Damage was classified into: not evident, mild, medium, serious or very serious. Damage due to concrete cover falling, delamination and erosion was limited (6%) in comparison to the cases where no damage was observed (88%). Where damage was apparent, it was mostly found at abutments (37%), parapets (18%), or deck surface near support (18%).

4.3.4. Alkali-Silica Reaction damage

During the damage survey carried out onsite as part of Level 2 data collection, damage due to alkali-silica reaction (ASR) in concrete was investigated. For each of the 16 bridges analyzed, observations for the following were recorded: damage at deck surface near support, damage at deck surface near midspan, damage at deck beam near support, damage at deck beam near midspan, damage at gerber supports, damage at pier cap, damage at pier top portion, damage at pier lower portion, damage at base- foundation, damage at abutments, damage at parapets, damage at connections, visible corrosion and efflorescence. These were classified into: not evident, mild, medium, serious or very serious. Damage due to ASR in concrete was very limited (1%) in comparison to the cases where no damage was observed (97%). This is due to the type of aggregate typically used in Israel, which is mainly of carbonate composition, such as limestone and dolomite, as opposed to silicate aggregates, which are less commonly used. Thus, damage due to ASR in concrete is somewhat irrelevant in Israel. Efflorescence of concrete was more commonly inspected, where mild to serious efflorescence was inspected in most cases. This type of damage can be seen in Fig. 10.

4.3.5. Global stability, foundation problems, impacts and local problems

During the damage survey carried out onsite as part of the Level 2 collection form in Israel, damage due to global stability, foundation problems, impacts and local problems was investigated. For each of the 16 bridges analyzed, observations for the following were recorded: evidence of foundation failure, evidence of slope problems, evidence of pier or terrain movements, evidence of pier immersed in water, risk of pier immersed in water in case of flood, evidence of erosion or loss of material in foundation, evidence of debris in the pier base, evidence of impact on deck, loss of material on deck beams, and evidence of impact on pier. The recordings were classified into either “Yes”, “No” or “Not relevant”. Damage due to global stability, foundation problems, impacts and local problems was limited (22%) in comparison to the cases where no damage was observed (69%). Where damage was apparent, it was mostly due to evidence of slope problems (29%), risk of pier immersed in water in case of flood (21%), evidence of pier or terrain movements (16%), or evidence of impact on deck (13%).



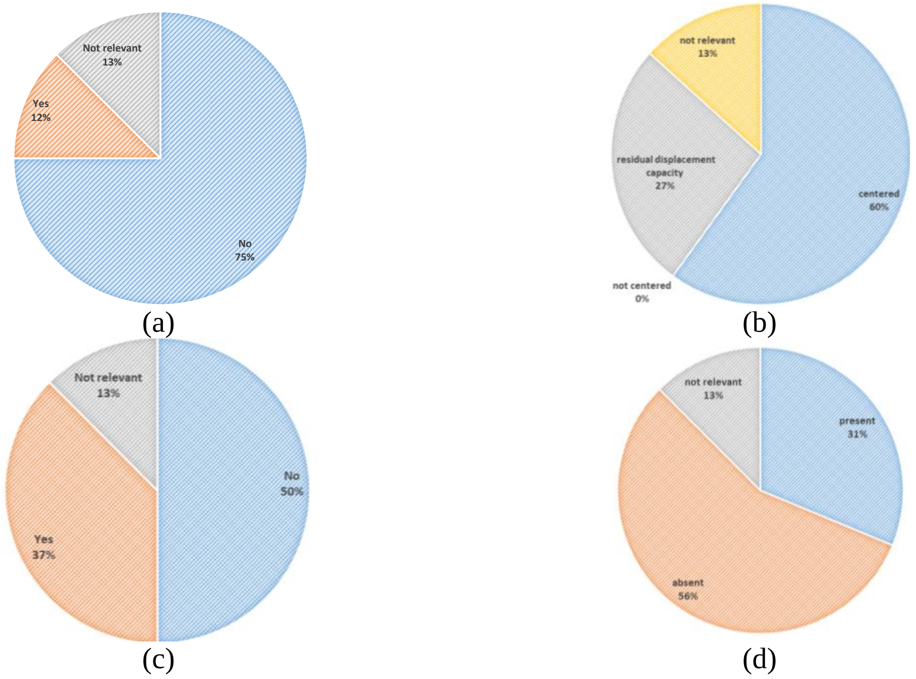
(a)

(b)

Fig. 10- Efflorescence damage to bridge elements

4.3.6. Support condition

During the damage survey carried out onsite as part of Level 2 data collection, the condition of supports was investigated. For each of the 16 bridges analyzed, observations for the following were recorded: support corrosion (Yes/ No), support stability (centered/ not centered/ residual displacement capacity), support transversal deformations (Poisson effect) (Yes/ No), and presence of debris (absent/ present). Fig. 11 summarizes these observations. Damage due to support corrosion was limited (12%) in comparison to the cases where no damage was observed (75%). Damage due to support stability was limited (27%) in comparison to the cases where no damage was observed (60%). Damage due to support transversal deformations was slightly limited (37%) in comparison to the cases where no damage was observed (50%). Presence of debris was slightly limited (31%) in comparison to the cases where no such phenomenon was observed (56%).



(a) (b)

(c) (d)

Fig. 11- Review of supports conditions in Level 2 bridges in Israel (a) corrosion, (b) stability, (c) transversal deformations, and (d) presence of debris

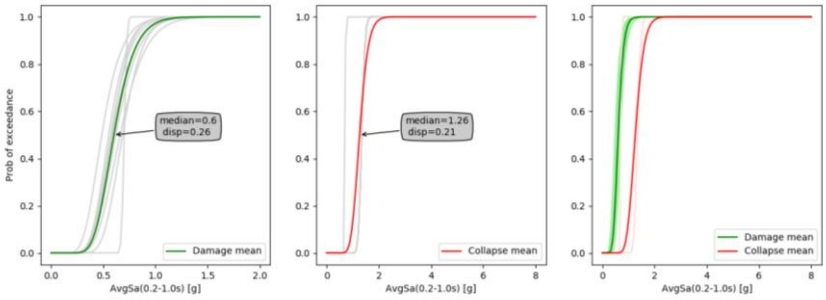
5. Results and discussion- fragility derivation

76 taxonomies, in total, were defined for the Israeli case. Each of the Level 1 bridges was classified into one of these taxonomies. For the bridge stock used in this project, a total of 47 out of the 76 taxonomies defined had entities other than zero. Level 2 detailed data collection phase included obtaining detailed design sheets and blueprints for 16 bridges, representing 13 different taxonomy groups. For each taxonomy group considered, a benchmark full FEM, based on blueprints, was created, and an order of 10 additional FEMs were created for each benchmark model, with variations in properties such as pier heights, span lengths, and deck width. Variations were assumed based statistical information gathered from bridges within the same taxonomy group. For example, for a bridge with piers heights of 7 meters, bridges with similar geometry but with pier heights of 5, 9, and 11 meters were also examined (these are referred to as “variations”). NLTH analysis was carried out for each of the bridges (benchmark and variations), using the BRI.T.N.E.Y platform, for 30 ground motion records fitted to the local Israeli seismic hazard model defined in INFRA-NAT project Deliverable D1.2 [4], for each of the 7 included intensity levels. Fragility computation was carried out for each model, so as to obtain its fragility parameters, and fragility curve parameters for the taxonomy group determined to be the average of the results obtained for each model (i.e. benchmark model and variation models). Some of the fragility parameters and curves obtained for the different taxonomy groups studied, using AvgSa (0.2-1.0s) as the ground motion shaking intensity measure, are shown in Table 1 as well as in Figs. 12-13. Full results can be found in INFRA-NAT project Deliverable D3.2 [3].

Further discussion on the results, as well as specific recommendations for good practice based on the results obtained can be found in INFRA-NAT project Deliverable D4.4 [5]. For example, some observations made, include: (a) a frame static scheme is generally less vulnerable than other static schemes, (b) a box/plate deck is generally less vulnerable then a beam deck, and (c) wall piers are generally less vulnerable than column piers, though vulnerability is also highly influenced by the type of connection between the pier and the deck. Despite the aforementioned observations, it is somewhat difficult to make clear conclusions as to what bridge parameters govern the fragility levels and overall behavior attained for each taxonomy group studied. Some taxonomy groups are more sensitive to variations in bridge parameters, while others are less sensitive to varying bridge element sizes/changes in geometry. Therefore, in order to allow better prioritization and decision-making in bridge treatment and resource/fund allocation, more specific investigation of the data obtained during the fragility assessment stage must be performed, and engineering insights must be considered. The main parameters investigated as part of this sensitivity analysis should be: (a) geometric sizing of the bridge elements and overall design, including: bridge spans, pier heights, deck width, etc, (b) bridge typology, including: static scheme, deck type, pier type, connection type, etc, and (c) bridge material (not relevant in current study, which focused mainly on RC bridges). It shall be noted that, where data is available, prioritization should also consider influences of soil type, foundation type, connection (bearing/isolation) type, material and overall deterioration level, etc.

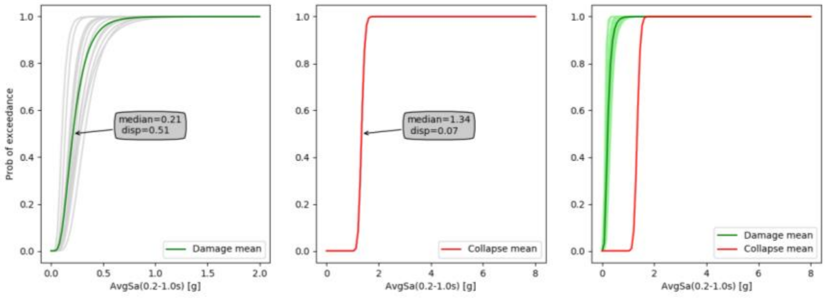
Table 1 – Summary of fragility curve parameters calculated for representative taxonomies

Taxonomy	**Limit State**			
	Damage		**Collapse**	
	Median [g] $\mu_{\ln Y}$	**Dispersion** $\sigma_{\ln Y}$	**Median [g]** $\mu_{\ln Y}$	**Dispersion** $\sigma_{\ln Y}$
RC-4/5-SS-BE-PO	0.478	0.356	1.068	0.346
RC-6+-SS-BE-PO	0.283	0.262	1.343	0.075
RC-4/5-C-BO-SC	0.251	0.568	1.343	0.075
RC-2/3-C-BE-PO	0.602	0.263	1.258	0.207
RC-4/5-C-BE-PO	0.21	0.513	1.343	0.075
RC-6+-SS-BE-SC	0.283	0.47	1.343	0.075
RC-4/5-C-BO-W	0.259	0.538	1.175	0.568
RC-4/5-F-P-SC	0.18	0.504	0.67	0.49
RC-4/5-F-BE-PO	0.484	0.53	1.209	0.629
RC-2/3-F-BE-PO	0.349	0.485	1.187	0.386
RC-2/3-F-BE-W	1.343	0.075	1.343	0.075
RC-6+-F-BE-SC	0.559	0.339	1.343	0.075
RC-6+-SS-BE-SC	0.489	0.404	2.878	0.824



(a) (b) (c)

Fig. 12- Fragility functions for the RC-2/3-C-B-MC taxonomy of the Israel case study: (a) Damage limit state, (b) Collapse limit state, (c) Summary



(a) (b) (c)

Fig. 13- Fragility functions for the RC-4/5-C-B-MC taxonomy of the Israel case study: (a) Damage limit state, (b) Collapse limit state, (c) Summary

6. Conclusions

This paper is focused on the Israeli case study of the INFRA-NAT project, promoting increased resilience of critical Infrastructure under seismic events. The results of a three-tiered data collection phase were presented and analyzed. Following the data-collection phase, typical bridge types were identified, and relevant taxonomy groups were defined. For each taxonomy group, NLTH analysis, for an ensemble of locally fitted ground motions was carried out, based on which fragility curves were built, using state-of-the-art procedures. Results obtained for 13 Israeli taxonomy groups were presented. This, for the first time in Israel, allowed for the characterization of fragility curves relevant to Israeli typical bridges, which can be used to assess seismic vulnerability of bridge infrastructure on a national level (such as integration for use in the HAZUS platform and similar uses), which in turn can assist decision makers with prioritizing seismic preparedness actions. A discussion on some results obtained, and recommendations for good practice based on study results were presented. These allow a better understanding from an engineering standpoint on current vulnerability of bridge stock in the State of Israel.

Nonetheless, the following should be taken into consideration with the abovementioned results of the case study. The results shown herein are based only on the information for approx. 100 bridges collected in Level 1 data collection phase for Israel, and not for the complete ~2100 count bridge stock in Israel (as collected in the Level 0 data collection phase). To create more realistic and representable results, which can be used by stakeholders and decision makers, the Level 1 collection phase (and to some extent, Level 2 collection phase) must be continued, in order to allow collection of information for missing bridges and include them in the WBP created as part of the INFRA-NAT project. i.e., the results shown herein showcase the abilities of the WBP in terms of its outcome, but the data currently available in the platform for the State of Israel is not enough, and is not sufficient in order to realistically asses the road network performance after a seismic event. There is considerable added value in continuing to add bridge information to the database, so as to have a better understanding of the complete effect, and to allow decision making by stakeholders on a national level.

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