BRAZILIAN BRIDGE MANAGEMENT SYSTEM: COMMENTS ON AXLE-LOAD VEHICLE*

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ABSTRACT

There is a general consensus that the problem of the Brazil's infrastructure is indeed a serious one and the consequences of not moving quickly to rectify it are grave. The health of the Brazilian economy depends on a healthy infrastructure, and if Brazil's infrastructure continues to deteriorate the economy will follow suit. Brazilian economy rests firmly on the infrastructure of its nation.

As the Brazilian bridge management system (SGO) has shown, severe damages of the structural elements can be accredited to the lack of a maintenance program and also for increase on truckload axle and traffic volume.

When the Brazilian highway system was built in the fifties, most of the structural highway bridge infrastructure was design conception for the standard load-capability of that time. This paper presents comments about the Brazilian vehicle axle load design and bridge management system.

Key words: axle load vehicle, bridge, highway, Brazil, infrastructure

REZUMAT

Există un consens general că problema infrastructurii din Brazilia este într-adevăr serioasă şi că a nu interveni rapid pentru a o remedia poate avea consecinţe grave. Sănătatea economiei braziliene depinde de o infrastructură sănătoasă, iar dacă infrastructura Braziliei continuă să se deterioreze, economia îi va urma. Economia braziliană se sprijină ferm pe infrastructura acestei naţiuni.

Aşa cum a arătat Sistemul Brazilian de Management al Podurilor, avarierile severe ale elementelor structurale pot fi puse pe seama lipsei unui program de întreţinere şi, de asemenea, pe seama creşterii volumului traficului şi al cantităţilor de marfă transportate.

La construirea, în anii '50, a sistemului brazilian de autostrăzi, majoritatea infrastructurii podurilor de autostradă a fost dimensionată pentru capacitatea de încărcare standard din acea epocă.

Articolul de faţă prezintă comentarii asupra proiectării la încărcări din trafic şi asupra sistemului de management al podurilor.

Cuvinte cheie: Vehicul rutier, pod, autostradă, Brazilia, infrastructură

1. INTRODUCTION

There is a general consensus that is going to be an economic decline due to gridlock and infrastructure failure to the point where Brazil no longer globally competitive, to the point where there is unemployment. Gridlock on Brazilian highways and roads are approaching the crisis stage, and the effects of this gridlock are beginning to impact the economy.

When the Brazilian highway system was built in the fifties, the people viewed this undertaking as an investment in the future. The investment in the future for the last twenty years has been one of disinvestment as opposed to investment, and when one disinvest, things start falling apart. It is becoming increasingly difficult to get a firm handle on the long term given the rapid rate of the nation's population and cars growth. The Brazil economy was not, is not, and will not be an economy unto itself. It has to be integrated within the world economy. And if you look at the South American region, there are five or six out of ten economies centered into Brazilian marketplace.

If Brazil continues to allow the infrastructure to degrade it will lose productivity, and that will affect it economy. If Brazil cannot transport goods to the marketplace in an economical way, it will lose

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economic competitiveness in the world. So when someone is talking about rebuilding Brazil's infrastructure it should take into account the fact that Brazil is a part of an integrated system. This means not only a Brazilian needs, but Brazil need to integrated those needs certainly with those of South American countries, and then extend beyond that a global view should be taken.

Maybe one of the first attempts in Brazil to carry out an inspection system for bridges maintenance was proposed by Professor Dr. Castro in 1976, who was at that time working with the Bridge Division of the Federal Highway Department (DNER). The paper presented by Dr. Castro was based on inspection procedures for assessing the bridge deterioration and for providing safety-based bridge information for maintenance program planning.

By 1980, a first Bridge Inspection Manual had been written by Professor Dr. Pfeil upon an agreement between the DNER and the Rio de Janeiro Federal University. However, according to Almeida (1995), it is through the Brazilian standard ABNT – NBR 9452, that requirements for bridges, maintenance, highways and railways came strongly to all those involved with transport along the country. Also, by that time, the DNER published the Bridges Rehabilitation Manual, (Dr. Souza and Mrs. Guimarães were the authors). This particular manual described all procedures needed for rehabilitation and repair of reinforced concrete structures.

Also, by the end of 80s, several circumstances had ensued Brazil-wide requiring that formerly applied highway operation and maintenance methods be changed. The intensive growth of traffic and, in particular, axle loads, increased the demand for roads and bridges. At the same time, as a consequence of significant network development activities and corrosion defects during the 70s, the actual maintenance needs of existing bridges increased sharply.

Under an agreement between DNER and MM/LOGIT (Maia Melo Engenharia Ltda and Logit Logística, Informática e Transporte Ltda,) the Federal Highway Department (DNER) developed a Bridge Management System (SGO) for application along the federal highways in Brazil. By the end of the 90's, several documents on SGO were written. The main purpose of that documents were to refer to the techniques already used for bridge inspection and survey, to point out funds needed for local and federal governments, and to call attention to correct design and construction procedures for engineers, including quality control.

Nowadays, Brazil has no sufficient financial resources for bridges maintenance and operation. The negative effect of postponing or delaying necessary bridge maintenance activities can be observed every day in any major city.

The following sections describe and characterize brief comments on vehicle axle loads, of the Brazilian highway and bridge management system.

2. BRAZILIAN HIGHWAY NETWORK ASPECTS

Brazil is approximately 8 514 466 km^2 in area and has almost 30 000 km rail network and a paved road network of over 92 761 km. The rail system is responsible for 23.4 % of the total transport of freight while the road system carries 58 % of freight being transported. The cabotage carries 10.1 % of freight, 4.89 % is transported by plane and 3.7 % by fluvial transport.

Table 1.

Road network length

	Population	Area (km2)	Road Network (km)	Total Bridges Length (km)	Bridges Number
NORTE	12900704	3853327	22,284.40	18.70	241
NORDESTE	47741711	1554257	25,825.60	74.30	1460
SUDESTE	72412411	924511	19,284.30	69.90	1137
SUL	25107616	576000	13,635.00	66.10	865
CENTRO-OESTE	11636728	1606371	13,641.80	27.70	434

The area of the country administrative geographic regions, 27 (twenty seven) Brazilian States, and their roads extension are shown in table 1. Paved roads and highways and its percentage on the total extension are also shown in that table.

The truck production in Brazil from 1957 up to 2006 is shown in table 2. A percentage of the trucks on the total vehicles produced in Brazil are also shown in that table.

3. BRAZILIAN STANDARDS ON TRAFFIC AXLE LOADS

By 1943, the Brazilian National Standard on highway bridges established three structural bridge classes namely: Class I, II and III. The load-capability was stated as a function of geographical location; span longer and load-capability. Between 1960 and 1984 the Bridges Classes were defined as a function of total axle-load vehicles of 36, 24 and 12 t. In 1984, the Brazilian bridge standard has change axle-load vehicle into 450 KN, 300 KN and 120 KN. All axle-load vehicles used along that years in Brazil bridge designs are shown in figure 1.

European standard, mainly the Germany DIN, had a strong influence on the Brazilian bridges standards. And Brazil has no significant statistical research on load traffic or real axle-load of trucks that runs on the roads and highways.

Bridges extension and amount by the country administrative geographic regions are also shown in table 1. The percentage of bridge extension and amount are shown in table 1 yet. Figure 2 shows the percentage axle-load vehicle distribution on Brazilian bridges.

Although, the Brazilian Bridge Management System (SGO) has shown significant improvement on providing an efficient maintenance program, there is no system for collecting data on truckload axle. There are only 15 (fifteen) points of load control along the Brazilian Federal Highway system. It is assumed that 77 % of the trucks running on Brazilians roads are over weighted.

According to EMS, 77 % of trucks do not meet the load limits established by law. This, apart from causing damage to the roads, also implies risks to the safety of drivers.

Table 2.

Truck production in Brazil

Year	Truck	Total of Vehicles	% of Trucks
1957	16,259	30,542	53.2
1958	26,998	60,983	44.3
1959	36,657	96,114	38.1
1960	37,810	133,041	28.4
1961	26,891	145,584	18.5
1962	36,174	191,194	18.9
1963	21,556	174,191	12.4
1964	21,790	183,707	11.9
1965	21,828	185,187	11.8
1966	31,098	224,609	13.8
1967	27,141	225,487	12.0
1968	40,642	279,715	14.5
1969	40,569	353,700	11.5
1970	38,388	416,089	9.2
1971	38,868	516,964	7.5
1972	53,557	622,171	8.6
1973	69,202	750,376	9.2
1974	79,413	905,920	8.8
1975	78,688	930,235	8.5
1976	83,891	986,611	8.5
1977	101,368	921,193	11.0
1978	86,269	1,064,014	8.1
1979	93,051	1,127,966	8.2
1980	102,017	1,165,174	8.8
1981	76,350	780,841	9.8
1982	46,698	859,270	5.4
1983	35,487	896,454	4.0
1984	48,497	864,652	5.6
1985	64,769	966,706	6.7
1986	84,544	1,056,332	8.0
1987	74,205	920,071	8.1
1988	71,810	1,068,756	6.7
1989	62,699	1,013,252	6.2
1990	51,597	914,466	5.6
1991	49,295	960,219	5.1
1992	32,025	1,073,861	3.0
1993	47,876	1,391,435	3.4
1994	64,137	1,581,389	4.1
1995	70,495	1,629,008	4.3
1996	48,712	1,804,328	2.7
1997	63,744	2,069,703	3.1
1998	63,773	1,586,291	4.0
1999	55,277	1,356,714	4.1
2000	71,686	1,691,240	4.2
2001	77,431	1,817,116	4.3
2002	68,558	1,791,530	3.8
2003	78,960	1,827,791	4.3
2004	107,338	2,317,227	4.6
2005	118,000	2,530,840	4.7
2006	106,001	2,611,034	4.1

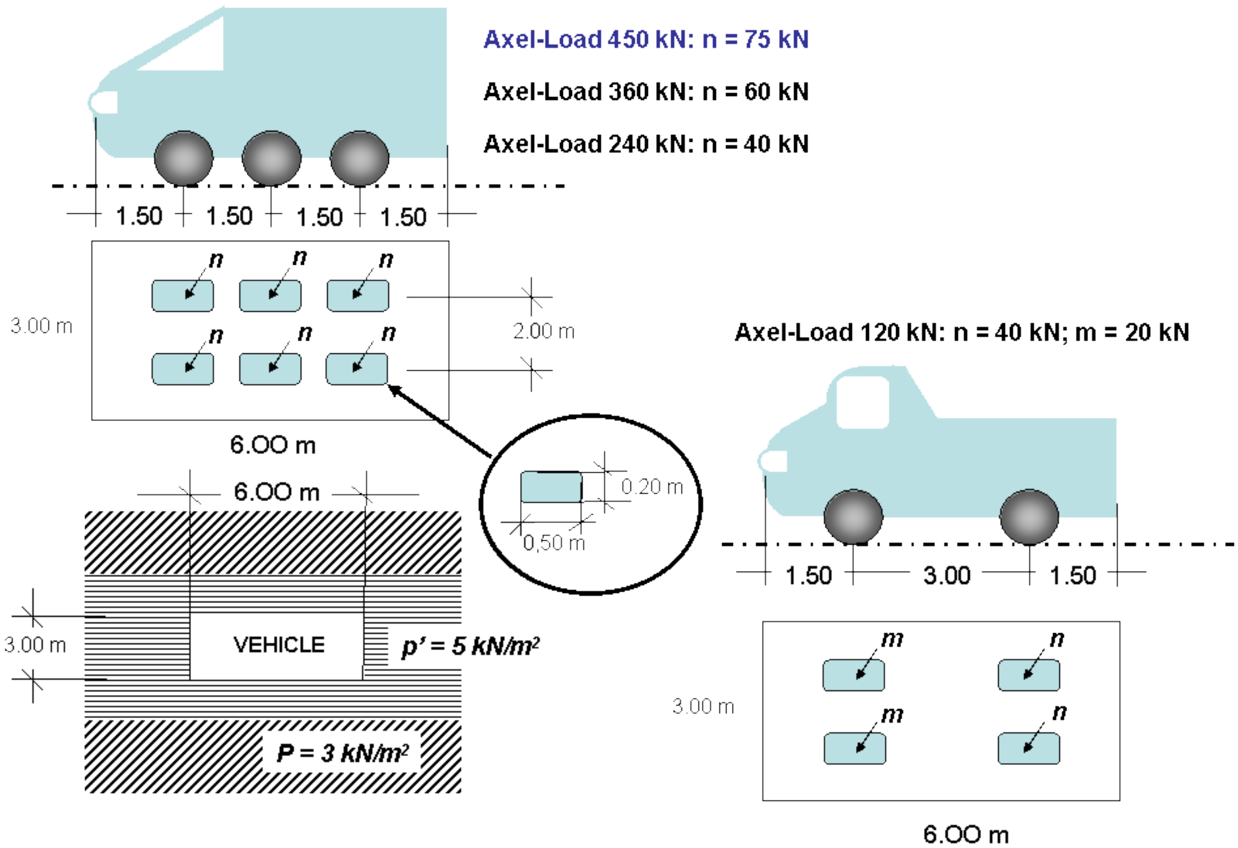

Figure 1. Bridge designs: axle-load vehicles used in Brazil

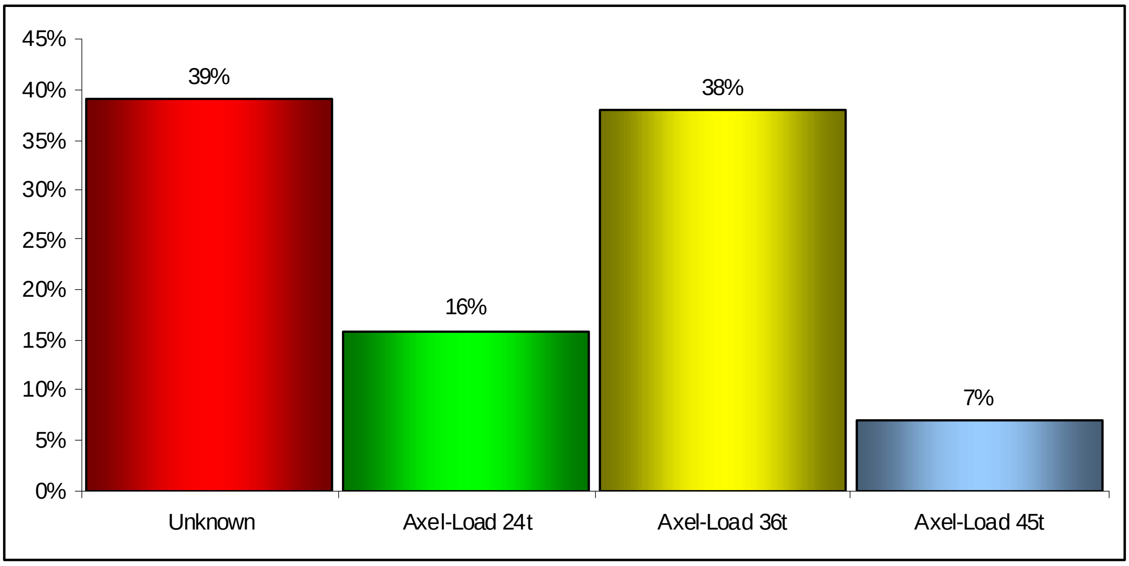

Figure 2. Axle-load vehicle distribution on brazilian bridges

4. BRIDGE MANAGEMENT SYSTEM

Bridge management means that all activities should be concentrated in a uniform system, which is necessary for the long-term and efficient preservation of the serviceability and longevity of highway bridges. Currently, several countries have already achieved significant results from the development of their systems, although they are rather different. The Brazilian continental dimensions, landscape characteristics, and climate regions require their own bridge management systems. No foreign system could be adapted and also be considered realistic to the financial resources of the Brazilian budget.

The Brazilian bridge management system (SGO) has been proactively involved in the planning, development, and implementation of its long-range comprehensive bridge safety assurance program, which is integrated into the DNIT (National Infrastructure Transport Department) a bridge management system. Therefore, SGO consists of selecting an optimal strategy for allocation of the budgetary means for maintaining bridges on the basis of information collected about their condition. The basic task of the SGO is to systematically generate information about the condition of bridges in management units, regions, countrywide and to allocate funds for maintenance, repairs and strengthening. All data, such as inventory and bridge condition, are registered and verified at the lowest level and transmitted to the higher level's DNIT authorities.

The main elements of the SGO are already more or less available, and are as follows: computerized bridge data bank, uniform procedure for bridge inspection, countrywide bridge maintenance programs, methods for calculation of the gross and net values of bridges, cost-benefit calculation method for bridge rehabilitation, and repair and strengthening.

The funds available for bridge maintenance, rehabilitation, and construction are far from below the realistic needs in Brazil. By the early part of 1990 the Federal Highway Department (DNER) was faced with almost 5.500 bridges and viaducts, along a total extension of 3000 kilometres, 35% of which, were assumed deficient, due to the deteriorating conditions. Many of these bridges were designed for lower traffic volumes, smaller vehicles, slower speeds, and lighter loads than are common today. Also many of them have not been adequately maintained.

These are reasons why the Ministry of Transport, through the DNIT, has initiated countrywide coordinated efforts to establish the Brazilian bridge maintenance system. The intensive growth of traffic and, in particular, axle loads increased the demand for roads and bridges. At the same time, as a consequence of significant network development activities' structural deterioration in the 80s, the actual maintenance needs of existing bridges increased sharply. However, nowadays there are insufficient financial resources for bridges maintenance and operation. The negative effect of postponing or delaying necessary bridge maintenance activities can be observed more often in the beginning of this century.

The main idea of the Bridge Maintenance System, named after SGO, was to implement a policy on management activities concentrated in a uniform system, which is necessary to the long-term and efficient preservation of the serviceability and longevity of highway bridges. Also, applying the Brazilian SGO - Bridge Maintenance System – deterioration rate for bridges in service, if known quantitatively, can provide direct evidence of the

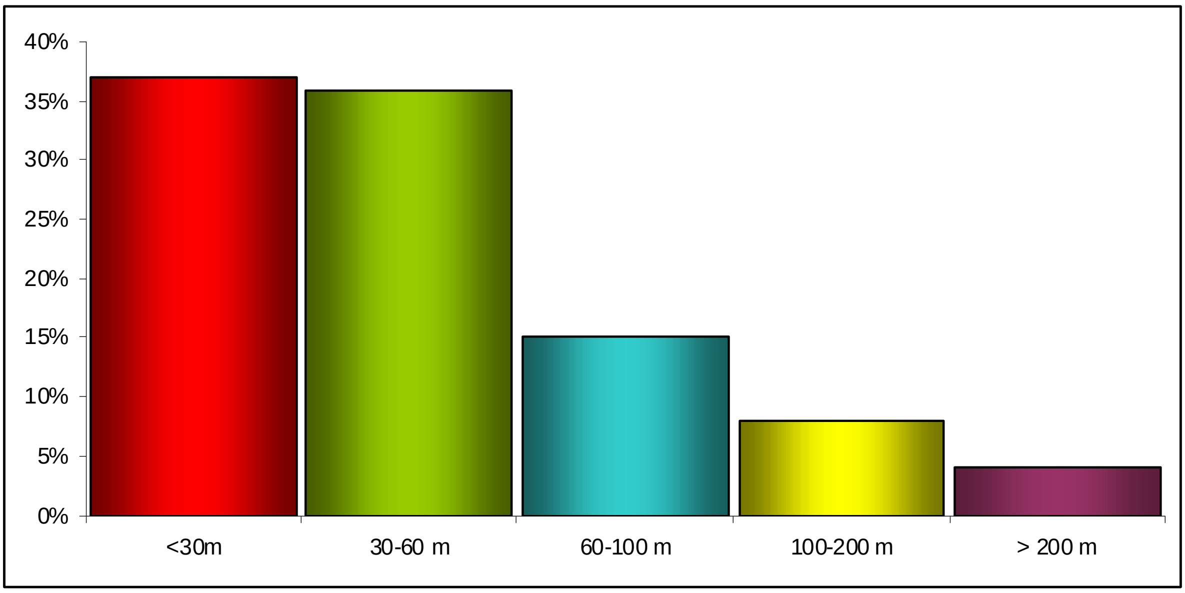

Figure 3. Bridge length distribution

performance of a particular design, details and structural materials. On following this policy, the Brazilian government is looking after the export product costs as a world trader country.

Approximately 35% of the bridges in Brazil are classified as deficient and in need of rehabilitation, strengthening or replacement. Of these bridges, many are classified as deficient because their load-carrying capacity is inadequate for today's increased traffic or increased axle loads. Bridges were designed for a 24-tons truck load during the 30s, 36-tons after the 60's, and currently the Brazilian standards state a 45-tons truck load for all bridges located on a Federal Highway.

The SGO inventory database has already listed more than 2400 bridges. The inventory database bridge length class is shown in figure 3, which also presents the percentage of bridge length listed.

Also, the inventory database is made up of collecting highway bridges' structural systems, physical and geometric characteristics, axle load allowed, neighbourhood to railway, ship channel, design characteristics and construction "as built".

The inventory database bridge provides information on detour routes, environmental attack, materials, etc. A computer screen is shown in figure 4 and 5.

The SGO is based on bridges' standard elements. This means that SGO requires inspection information as bridges have always been categorized into various components, and each one has been rated according to the condition's severity. Under the SGO, system bridge elements are defined and rating will include both severity and extend deterioration.

5. INSPECTION SYSTEM

The heart of the SGO is the new rules of inspection. The rating condition for structural elements, and also the scale of condition rating. For instance:

- No problems, no repair is needed, only conservation works;
- Small dysfunctions which do not need repair, but conservation work;
- Defects which must be repaired, followed by conservation work;
- Serious damage which may be dangerous for bridge safety, need repair;
- Very serious damage, which is very dangerous for bridge safety, emergency repair is needed.

Also a scale of serviceability rating like:

- Operations without restriction, full serviceability;
- Operations without restriction, small dysfunctions like noise, ugly appearance;
- Operations with restriction of the clearance on the bridge;
- Operation with the lower speed;
- Operations with reduced axle load on the structure;
- Structure out of use.

6. PATHOLOGICAL ASPECTS

An indispensable condition for the function of the system is unequivocal location of bridges and roads. The method adopted would allow the whole SGO system to be independent of any administrative organizational changes, and it would be possible to combine the existing location database with any reference system describing the highway net.

Repair, rehabilitation and strengthening are based on the urgency of the features that need the service action. Making a decision about service action is determined by a series of circumstances and events. Therefore, the decision space around each bridge can be described by a set of arguments that, by their description, reveal the importance of these features. Therefore, decisions are made in regards to a set of information based on feature's parameters: economic, technical, durability, highway class and work urgency. Economic is based on costs – user cost, Technical is related to service performance. Durability is analysed on degree of deterioration. Highway class is related to traffic volume and agricultural and industrial products transport. Work urgency is an absolute priority for carrying out service action on bridges, assuming a collapse or keeping track of service performance.

The main anomalies' occurrences listed in the Inventory Database are shown in table 3. No pathological occurrences with percentile less than 15 % were written down in table 3.

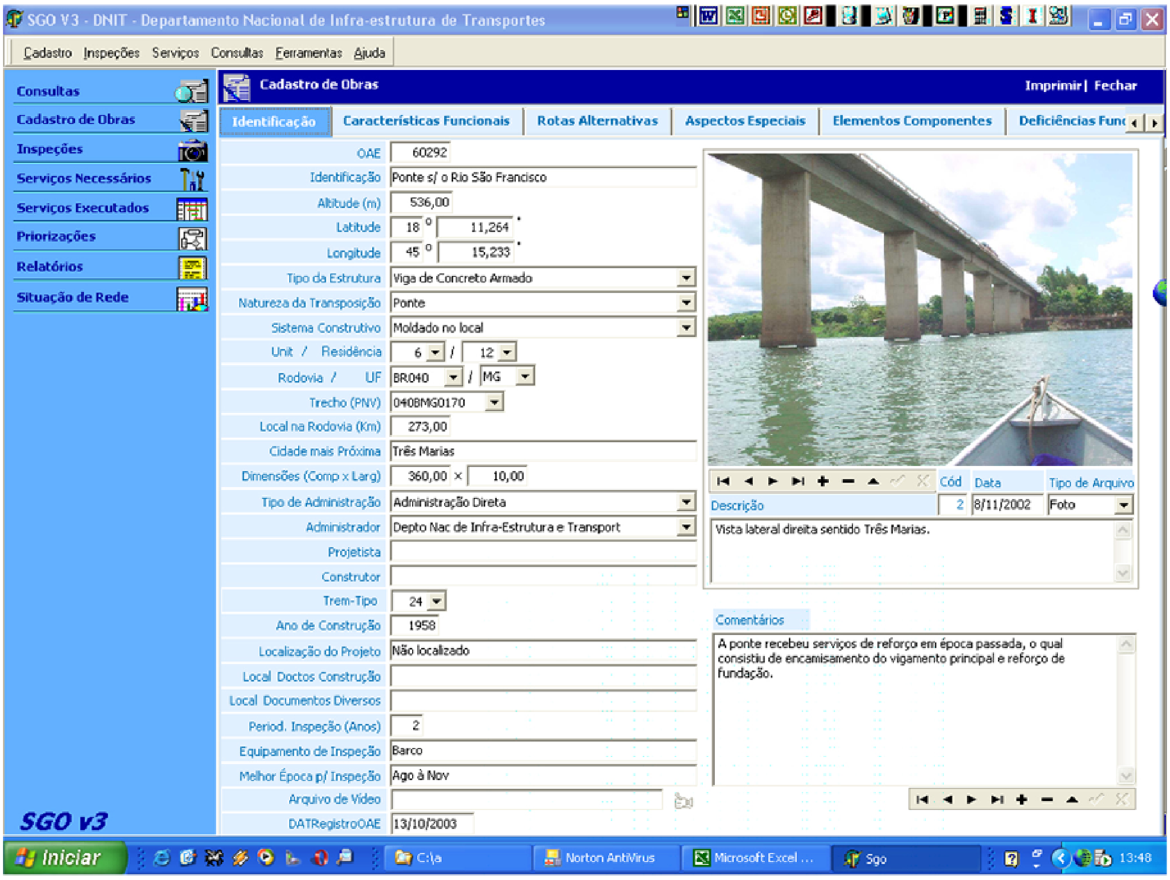

Figure 4. A windows screen inventory database bridge

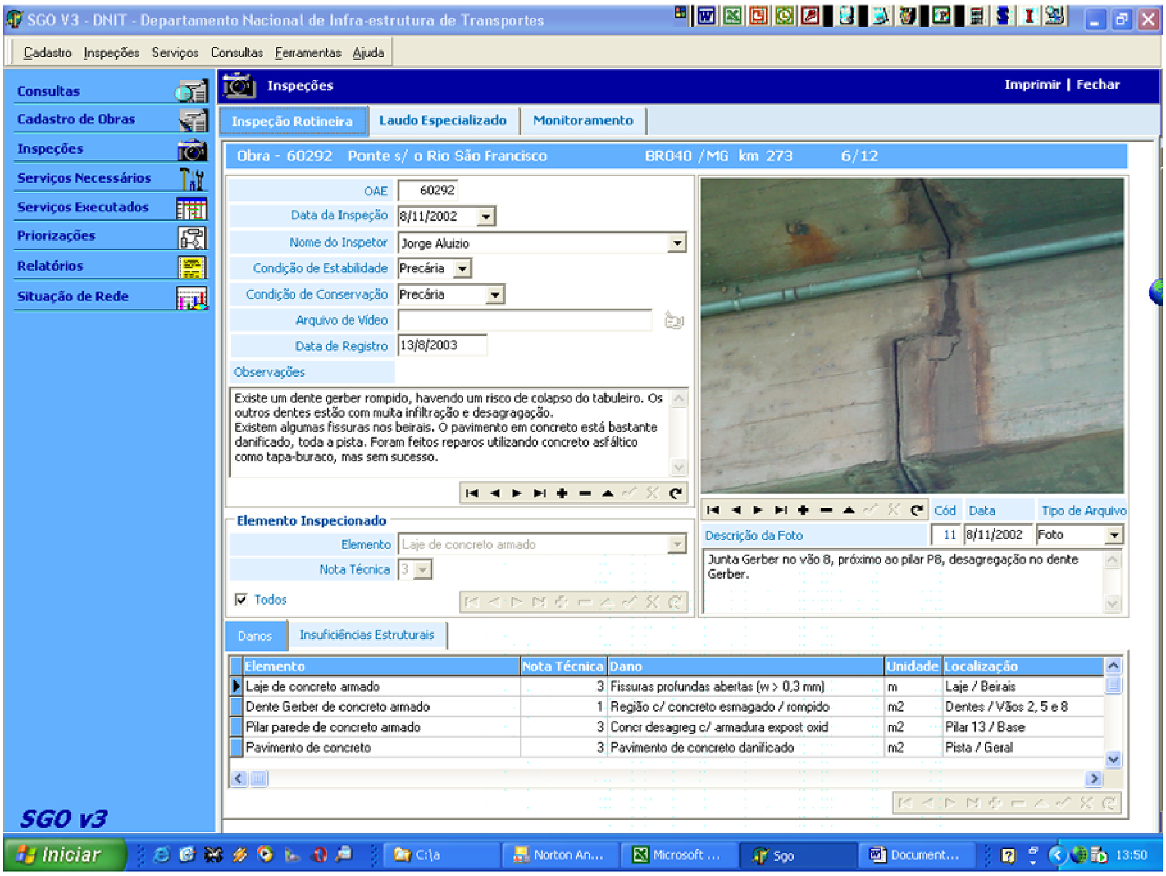

Figure 5. A bridge inventory database

Table 3.

Inventory database mainly anomalies listed

ANOMALY	LOCATION	%
No drip groove	Main Girders/Deck	67
Asphalt layer with slightly deterioration	Road lane/ approach	59
Injected crack	Piers	46
Damaged bridge parapet	Deck/approach	44
Concrete segregation	Girders/Deck	39
Asphalt layer with severe deterioration	Road lane/ approach	34
Honeycomb	Girders/Deck	33
Concrete segregation with corrosion to the reinforcement bars	Girders/Deck	32
Sealed crack	Piers	30
Injected crack	Girders/Deckj	27
Concrete segregation with corrosion to the reinforcement bars	Girders	22
Honeycomb	Piers	22
Concrete segregation with corrosion to the reinforcement bars	Piers	20
No drainage system	Girders/Deck	18
Injected crack	Girders	18

Most of pathological degree of deterioration, imperfection or damage in bridges' structural elements is provided by the lack of a maintenance management program. Viewers of the anomaly frequency number are dazzled by the figures that they face before them. A single picture of the anomaly will show no significant difference between their characteristics by their locating at foundation, piers or superstructure.

The SGO inventory database reports are broad enough to point out that failures might be due to:

- Ignorance: which includes: incompetent men in charge of design, construction, or inspection; supervision and maintenance by men without necessary training or expertise; supervision and maintenance by men without necessary experience; assumption of vital responsibility by men without necessary training or expertise; competition without supervision; and / or lack of sufficient preliminary information;
- Economy: in first cost and in maintenance;
- Lapses or carelessness: an engineer or architect, otherwise careful and competent, shows negligence in some certain part of the work; lack of proper coordination in production of plans.

Deterioration of reinforced concrete foundation elements, piers, girders and deck come up with corrosion of the steel bars, overgrowing of weed or shrub, road-surface layers popout. Generally, the anomalies became so severe due to the lack of a maintenance management system.

7. CLOSING REMARKS

By the end of the 50 s and during the 70 s, Brazil built up a large highway network. However, no policy on maintenance was developed for quite some time. Therefore, most of the bridges are 50 years old and structural deterioration is the heart of the Bridge Maintenance System, for decision makers on financial fund and cost-benefit analysis.

The structural bridge system of the Brazilian highways bridges were bright design conception for that early years of the fifties. However, most of the severe damages of the structural elements can be accredited to the lack of a maintenance program and also for increase on truckload axle and traffic volume. Under those hard conditions the highways bridges, 50 year performance is a challenge for the current structural designers and management systems.

An amount of 327,469 death on traffic accidents in Brazil have occurred during the last 10 (ten) years. This means one of each 25 Brazilians get dead by traffic per year, or 98 deaths per day. In Brazil, the death rate per thousand km of highway is of 107, that may be compared with Italy and Germany rate of 10 and with 7 of the USA. According to the Brazilian Government there are 35,000 traffic deaths per year that can be compared to the 37, 000 demises of Iraq war.

Brazilian deteriorating bridges and pavements will definitely result in more deaths on our highways. The root of the bridges deterioration problem is that the structural systems are taken or granted. The population is trained to wait for failure to make improvements. The people who vote for the politicians and the politicians that vote for funds have not been educated on the importance of the infrastructure, mainly on bridges as link of two production points. All parts have taken away from the designers the life-cycle concept so that there is a political apathy because there is no crisis. In many ways what Brazil needs to do has to be very different from what it has been done in the past. And that becomes an enormous challenge.

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