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Health evaluation over paver block pavements based on ISO 2631-1 and NHO 09 regulations

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Resumo: É fundamental que os pavimentos ofereçam tráfego fluído, conforto e ausência de riscos à saúde dos usuários. Ainda, fatores a se observa são a poluição da cadeia produtiva e a capacidade de drenagem. Pavimentos flexíveis e rígidos convencionais apresentam desempenho de drenagem consideravelmente limitado, além de não serem sustentáveis em sua produção. Uma solução para caminhos frequentemente negligenciados, conhecidos como baixo volume (ruas e estradas), e ecologicamente positivos, são os pavimentos de *paver*. Os *pavers* são sustentáveis e apresentam bom desempenho na drenagem de precipitações. Este artigo tem como objetivo através das normativas ISO 2631-1 e NHO 09 de vibrações verificar se os estados resultantes de suas avaliações sobre os caminhos de *pavers* são semelhantes, comparar os valores da ISO 2631-1 com a literatura e discutir se diferentes arranjos dos *pavers* podem produzir mais vibrações. O equipamento utilizado consiste em um suporte veicular para inserir o celular que registra as vibrações através de seu acelerômetro e um reboque engatado no carro utilizado para medir as vibrações sobre as mesmas vias. Outra finalidade é verificar se existe correlação entre os sistemas de coleta de vibração, oferecendo um modelo que não seja dependente do modelo do veículo para observar o nível de vibrações transmitidas pelo pavimento de *pavers*. Este trabalho concluiu que a NHO-09 classificou de forma mais branda os caminhos utilizados que a ISO 2631-1, uma possível relação das vibrações elevadas com a disposição dos *pavers* do pavimento e valores de vibrações relacionáveis com a literatura.

Palavras-chave: *Paver*; vibrações; pavimentos sustentáveis; higiene ocupacional.

Abstract: It is essential that pavements offer traffic flow, comfort and no health risks for their users. Still, it is important to be aware of the pollution created in their produce chain and drainage capacity. Conventional flexible and rigid pavements have a considerable limited drainage performance besides being not sustainable in their production. A solution for pathways that are frequently neglected, usually low-volume pathways (streets and roads) and environment friendly are paver blocks pavements. Paver blocks are sustainable and have a good performance in the drainage of precipitation, furthermore. This article aims though ISO 2631-1 and NHO 09 evaluations of vibrations

over paver blocks on low-volume pathways to check if the evaluations resulting conditions are similar, to compare ISO 2631-1 values obtained with literature values and discuss if different arrangements of paver blocks can produce more vibrations. The equipment used consists of a car support to insert the cellphone which recorded vibrations though its accelerometer and a simple utility trailer towable to the car used to measure vibrations on the same pathway afterward. Other purpose is verify if there is a correlation between the last one and the support car, offering a model that is not dependable on the car model to observe the level of vibrations transmitted by the paver block pavement. This paper reached that NHO-09 classified milder than ISO 2631-1 the performance of pavements, possible relation of higher vibrations with the arrangement of paver and values of vibrations relatable to the literature.

Keywords: Paver blocks; Vibrations; Sustainable pavements; Occupational Hygiene

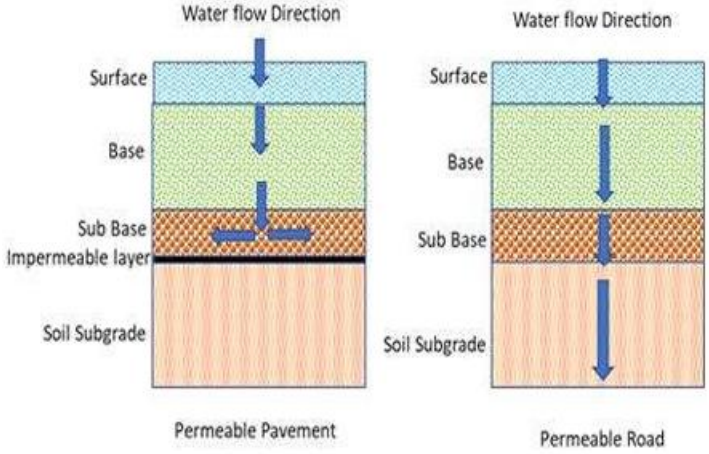
1. Introduction

Routine and Labor is directly related to transportation. The Bureau of Transportation Statistics (BTS) of the United States Department of Transportation (USDOT) estimated over sixteen million of people working in the transportation and related industries in 2023, being a increase of 1.7% from 2022 (BTS, 2024). It is not a particular fact from the United States: Brazil has approximately 1.9 million of truckers workers (CAMARA, 2024) and 1.5 million working as applications drivers as reported from brazillian agency *Instituto Brasileiro de Geografia e Estatística* (IBGE) (2023). It being observed in a big aspect, most of the population are drivers or are driven to their activities, being exposed to the vibrations produced by the chock of vehicle with the surface their routes.

Pavements and unpaved roads are not just considered positive pathways to society drive along by performing low vibrations to users but also matters if it has drainage quality to avoid floods. Floods causes monetary damages and healthy hazards to population, specially to marginalized people (Doocy *et al.*, 2013). Llewellyn (2006) cited by Doocy *et al.* (2013) indicated that 3.7 billion dollars were spent annualy in U.S. from 1988 to 1997 and an average of 110 deaths per year counted in the period of 1940 to 1999. The savanne zone of Niger registered from 1970 to 2000 79 damagleable rains and floods in communities (almost two per year) being the result of 27,289 homeless people, 18 deaths, and caused over $4 million in damages (Tarhule, 2005 *apud* Doocy *et al.*, 2013). Tarhule cited by Doocy *et al.* (2013) also reported that polutation were questioned about the main causes of periodic floods indicating the drainage problem along other four causes. In a scenario dominated by the density of constructions in cities, independently if they are big or small ones, it is importante to provide a good system of drainage to avoid floods and their related problems.

One material that has gained certain focus in infraestructure is the paver block. Also know as interlocking block due to its geometry that one side of theblock can fit to the other block's side, it is a material mostly produced of concrete with growing possibilities of using recycled waste in its mixture and minimizing CO2 foot (TAKAHASHI & CORACINI, 2021). The installment of paver blocks depends of the subgrade, sub base, base and superficial sand to fix the blocks and use as joints between them (ARAUJO & DOURADO, 2020). These spaces between blocks and even the utilization of porous blocks avoid the runoff water. The Figure 1 shows the possibilities of water comportment in paver blocks as they are permeable in its surface, allowing the filtrage of water to lower layers conducting water to a drainage system or to the local soil. Mamperachi and Gunatilake (2013) presented a comparitive study of paver blocks and conventional pavements reaching that paver blocks provided the lowest cost in a life cycle from all materials. Not least other advantagens are mentioned by Araujo and Dourado (2020) as minimizing heat island zones, decrease in public lightning due to its lighter colours in comparition to conventional pavements and others.

Figure 1 – Permeability of Paver blocks pavement.



Font: Adapted from Varkey *et. al.* (2020)

This article main objective is assess the vibration level of paver blocks in seven sites of Guarapuava - Paraná, under levels stablished by ISO 2631-1 and NHO-09 to avaluate the accelerations (parameter) detected to users, consequently, to vehichles (higher repair costs and prone to acidentes). Specific objectives are: to observe differences in condition classification of the pathways from ISO 2631-1 to NHO-09, to compare values obtained from ISO 2631-1 with most relatable values on literature and to discuss possible connexion between the arrangment of paver blocks with higher vibrations.

The objects of avaluation are: five parklots and two streets. Three of them are located in the newest neighborhood of the city, called City of Lakes (*Cidades dos Lagos*). Probably due to the aesthetics, efficient execution and performance obtained by pavers blocks the surface of the main street of Guarapuava, the 15th of November street (Rua Quinze de Novembro) has been substituiated asphalt to paver blocks as shown in the Figure 2. It is interessting that this renovation defines a sharedway with vehicles passing by grey blocks and pedestrian in the red blocks.

Figure 2 – Execution of the new 15th of November street in paver blocks

Font: Author (2024)

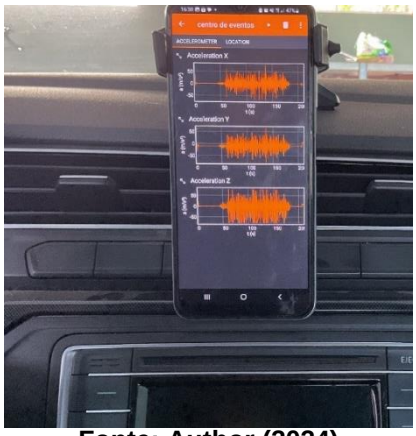
The spreading of paver blocks pavements both locally and nationally like observed in Ceará state of 37% in 2023 from 2022 shows and important object to study (XIMENES, 2023). The assessment of pavers as good surface layer to pavements also in matter of vibration to vehicles and passenger not just allow it application in more sites but also achieve some Sustainable Development Goals (SDGs) as: Decent Work and Economic Growth (SDG 8) and Industry, Innovation and Infrastructure (SDG9) besides Sustainable Cities and

Communities (SDG 11) and Climate Action (SDG 13) are broghout by the product life of paver blocks and their porosity caracteristic mentioned before.

2. Equipments

The vibrations inside the vehichle which is a Volkswagen Gol Track 82 cv. 2018 model (fabricated in 2017) were obtained by the cellphone acelerometer. The cellphone has used a Galaxy A22 5G (SM-A226BR/DSN) which was plugged in the original support for cellphone of the vehicle with the application Phyphox to record the vibrations recognized by the acelerometer inside the car. The Figure 3 shows the system described.

Figure 3 – Fixed cellphone with Phyphox recording vibrations



Fonte: Author (2024)

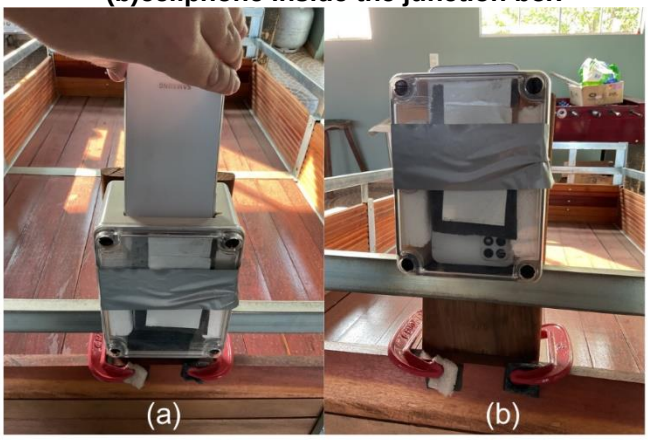
The outside vibrations were caught by the utilitary trailer plugged in the car by a tow ball, a spherical connection component mounted on the rear of a vehicle, designed to attach a trailer or caravan. The ball allows the trailer to pivot smoothly in all directions while being towed, ensuring stability and maneuverability. The trailer used to focus on studies not dependent in car models to measure vibrations is the one in the Figure 4. As expressed, this system was adopted to not depende on values of a certain vehicle being an accessible option to studies compare results with each other and standardize evaluation with the trailer.

Figura 4 – Utility trailer towed to author's vehicle

Fonte: Author (2024)

In matter of size the utility trailer used has a distance from the middle of the left tire to right tire's middle of 1.45 meters being the same axle size of the vehicle used. The weight of the trailer utility is 570 kilograms including its wood body. Then a attaching device was developed to safely carry the cellphone using the utility trailer: a wood bar was fixed verticaly in the body of the utility trailer with G-clamps guaranteeing that the bar was rigid enought for the measurings with no possibility of displacements during them consequently compromising the sequent recordings. In the wooden bar was screwed a windowed juction box with a hole over it to put the cellphone inside the compartiment fullied of thick Polyethilene foam to ocupy spaces and avoid residual displacements inside the juction box. Figure 5 (a) ilustrates the placement of cellphone and Figure 5 (b) shows the cellphone inside the junction box with phyphox vibration mode activated and camera recording vídeo

Figure 5 – System developed to attach cellphone in the utility car: (a) inserting the cellphone; (b)cellphone inside the junction box



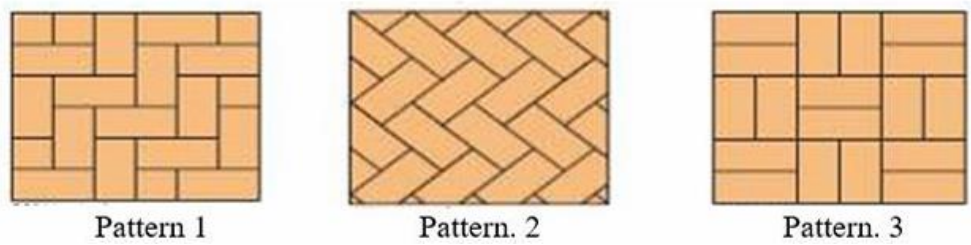
Font: Author (2024)

3. Objects of Study

The pathways evaluated were streets and parklots paved in diferente times and this aspect was not taken into consideration into the analysis made. The shape of paver blocks of the areas investigated were all retangular classified as Class I for the brazilian normative NBR 9781 (ABNT, 2013). Altough the brazilian normative defines mechanical results that blocks must have to be accepted, there are no comparative between shapes.

There are studies about the impact of shapes in paver blocks and patters of interlocking: Rachmat and Salsabilla (2019) presented results over different block shape's with equal thickness under same stress and concluded that the hexagonal geometry is the most efficient in matter of producing the lowest deformations and moments followed up by rectangle (there were the cube and circle shape too); Yusuf (2024) reported that over three different thickness of paver blocks the pattern formed by obliques pieces resisted highest loads in tests, followed up by pattern two and pattern three considering the vehicle moving vertically from the basis of the pattern to the top. Figure 6 shows the patterns evaluated by Yusuf (2024).

Figure 6 – Patterns of interlocking retangle blocks



Font: Yusuf (2024)

There were no specific acceleration values for paver blocks pavements in literature although in the paper by Múčka (2022) collected values of ISO 2631-1 accelerations across literature for different pavements, different vehicles and different ranges of speeds. The results of Kaderli and Gomes (2015) and Vella *et al.* (2020) cited by Múčka will be compared to the ones produced by this work: both of studies have results for Cobble stone pavements which is a pavement with execution process very similar to the executed in paver blocks. Kaderli and Gomes (2015) experiment was produced with passenger cars collecting vibration from driver's seat to evaluate total vibration finding to speeds of 30 km/h and 60 km/h respective values of 0.72 and 0.91 m/s². Vella *et al.* (2020) found for speeds of 5 to 40 km/h accelerations lower than 1.25 m/s² collecting from driver's seat for evaluating total vibration too.

The sites that were recorded vibrations have the extesions and pattern classification of Yusuf (2024) presented in Table 1. The speed range took to driven by these pathways was 0 – 40 km/h which are related to the start of movement to the maximum speed indicated by signals to move in the parking lots and streets. Interresting point about speeds is that the higher it gets the higher frequencies can get too (MÚČKA, 2022). The Mourao parking lot has a * in it because the paver surface was under a layer of crushed stone the usual type used in constructions.

Table 1 – Streets and park lots investigated and related aspects

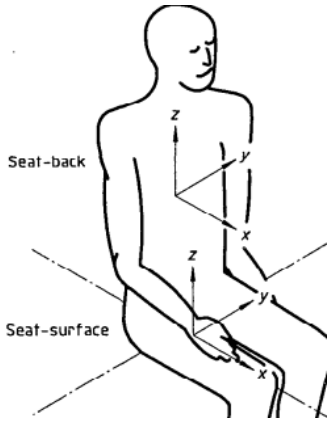
Investigation site	Extension (m)	Percentage (%)	Shape / Pattern
Three Tower Street coord.: 25º 21' 01'' S / 51º 28' 25'' W	637.68	28.68%	Retangular / no. 1
Jordao Street coord.: 25º 24' 24'' S / 51º 27' 34'' W	110.28	4.96%	Retangular / no. 1
City of Lakes Events Center Parking Lot coord.: 25º 20' 29'' S / 51º 27' 51'' W	825.02	37.10%	Retangular / no. 2
Coamo Parking Lot coord.: 25º 21' 58'' S / 51º 28' 28'' W	150.40	6.76%	Retangular / no. 1*
Cancer Center Hospital Parking Lot coord.: 25º 20' 38'' S / 51º 28' 21'' W	210.08	9.45%	Retangular / no. 1
Icavel Parking Lot coord.: 25º 21' 57'' S / 51º 28' 41'' W	253.26	11.39%	Retangular / no. 1
Mourao Parking Lot coord.: 25º 21' 21'' S / 51º 27' 40'' W	37.00	1.66%	Retangular / no. 1
TOTAL (m):	2223.72	100.00%	-

Font: Author (2024)

4. Analysis procedures

This section discuss equal actions to both ISO 2631-1 (ISO, 1997) and NHO-09 (FUNDACENTRO, 2005). The vibrations measured from the cellphone attached in the trailer and car support were recorded in a 500 Hz ratio. It means that for each second 500 accelerations were recorded in the three axles (x, y, z). The coordinates system is the same for both normatives and is presented in Figure 7. Therefore processing the obtained data from the pathways, each acceleration direction was defined if x, y and z to procede with the avaluation. Since the analysis was made without sensors in the back, feet and hands, so the analysis for both points of vibration recording was the whole body effect and the explanation to Figure 7 only shows the seated position.

Figure 7 – Axles adopted by both regulations applied in the study



Font: ISO 2631-1 (1997)

The root-mean-square (RMS) was submitted over each second of vibration recordings to be used separated to ISO 2631-1 evaluation and NHO-09 evaluation considering which values were necessary and asked weightings. Obtained the RMS (the root of the sum of every acceleration value, happened in one second, squared and divided then to the number of terms) on three axles proceeded to the vectorial sum (sum of the three accelerations powered by two and rooted then) and proceded to the average of the course. Table 2 shows the results for each investigation site undergo the previous process described corresponding if the measure was caught from trailer or support.

Table 2 – Results of Accelerations post RMS and simple vectorial sum

Investigation site	Course Duration (s)	Trailer Resulting Acceleration (m/s²)	Standard deviation - Trailer Resulting Acceleration (m/s²)	Support Resulting Acceleration (m/s²)	Standard deviation - Support Resulting Acceleration (m/s²)
Three Tower Street	98	16.04	3.50	10.04	0.25
Jordao Street	20	18.22	5.09	10.02	0.19
City of Lakes Events Center Parking Lot	124	20.86	4.54	10.10	0.15
Coamo Parking Lot	30	16.56	3.47	10.09	0.15
Cancer Center Hospital Parking Lot	45	15.13	2.91	10.06	0.22
Icavel Parking Lot	50	18.83	6.12	10.11	0.17
Mourao Parking Lot	15	17.13	8.21	11.84	5.43
AVERAGE	**54.57**	**17.54**	**4.83**	**10.32**	**0.94**

Font: Author (2024)

Attempts of correlating the resultings accelerations were done (support resulting acceleration *versus* trailer resulting acceleration) using all 382 accelerations collect for each system. The types of functions were: log, exp, power and polynomial of level 1 and 2. The closest square R obtained was equal to 0.0052.

5. Vibration normatives

The International Standard Organization (ISSO) released the 2631 standard in 1997 to evaluate different types of vibration. The part one of the document is concerned about vibrations on whole body and their affects over user comfort, motion sickness and health. The last aspect is the one that matters in this study. The document indicates that the relevant direction to evaluate vibration in the whole body is the axle that presents the highest frequency in the the range of 0.5 Hz to 80 Hz which are frequencies that affects human health. The Fourier transform was used to estimate which axle had the top frequency of each path of the study. Table 3 relates courses and vibration system to the most representative axle and its value of frequency.

Table 3 – Axles of hightest frequency in the measures followed up by its value

Investigation site	Axle of highest frequency - trailer recording	Value of the highest frequency - trailer recording (Hz)	Axle of highest frequency - trailer recording	Value of the highest frequency - trailer recording (Hz)
Three Tower Street	Z	4.65	Y	25.40
Jordao Street	Z	15.32	Z	36.77
City of Lakes Events Center Parking Lot	X	17.64	Y	36.70
Coamo Parking Lot	X	15.64	Y	31.52
Cancer Center Hospital Parking Lot	X	18.05	Z	1.93
Icavel Parking Lot	X	15.75	Y	31.03
Mourao Parking Lot	X	16.91	Y	0.75

Font: Author (2024)

Besides defining the axle most representative ISO 2631-1 reports that if "... vibration in two or more axles is comparable, the vector sum is sometimes used to estimate health risk" (ISO, 1997, p.13). The normative does not stablish what proportion a axle must have to be comparable to another. In this aspect was necessary to call on EN 1032 (apud SOUSA, 2021) (european document to evaluate vibration) to use its recomendation that if an axle has average acceleration in the transformed work journey of 66% of the one with the highest frequency, it must be considered in a vectorial sum. The comparision must be using the weightnings indicated by ISO 2631-1 which are 1.4 to axles x and y and 1 to axle z.The called transformed work journey refers to the the root of the time took to measure vibration over the regular work journey. The equation of the average acceleration multiplied by the transformed work journey is seen in Equation 1.

$$a(8) = a_{re}\sqrt{\frac{T}{To}} \quad (1)$$

Where:

a(8): Acceleration transformed to the work journey of eight hours;

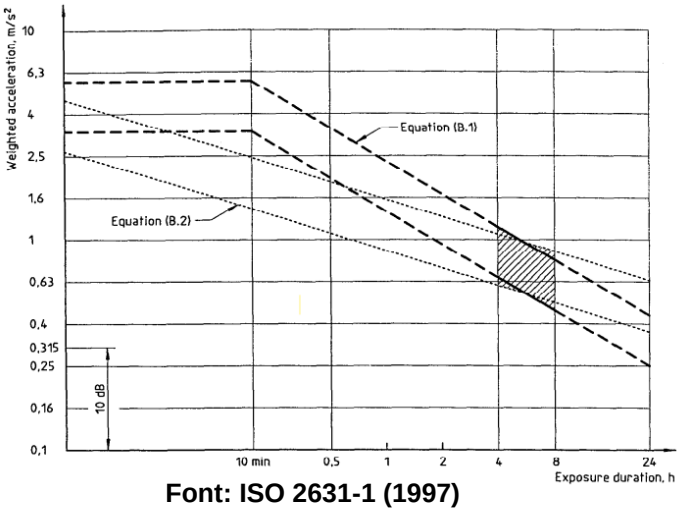
a_{re}: Average resulting acceleration obtained after RMS and weightning vector sum;

T: Exposure/duration of vibration measure in seconds;

T_0: Work journey, used 28,800 seconds that is equal to 8 hours.

Evaluating if repeted accelerations can produce under long periods hazard to human health is conducted by ISO 2631-1 Annex B graph illustraded by Figure 8. The dashed lines marked with an arrow written Equation (B.1) are based on the transformed journey, duration of exposure cited before while the doted lines with Equation (B.2) the root is not square but fourth (1/4). As NHO-09 uses the square root to transforme duration of exposure over a eight work journey too, it will be considered under 0.45 m/s² as no risk; between 0.45 m/s² and 0.9 m/s² as probable and over 0.90 as risky like considered by Killen and Eger (2016). Table 4 presents the paver block pathways classified in both vibration systems

Figure 8 – ISO 2631-1 Exposion lines to evaluate acceleration if it is risky, potencial risky or no risky



Font: ISO 2631-1 (1997)

Table 4: Final Accelerations for ISO 2631-1 evaluation and their following classifications

Investigation site	ISO 2631-1 trailer a(8) (m/s²)	ISO 2631-1 trailer condition	ISO 2631-1 support a(8) (m/s²)	ISO 2631-1 support condition
Three Tower Street	1.03	HEALTH RISK	0.61	POTENCIAL HEALTH RISK
Jordao Street	0.54	POTENCIAL HEALTH RISK	0.26	NO RISK
City of Lakes Events Center Parking Lot	1.78	HEALTH RISK	0.92	HEALTH RISK
Coamo Parking Lot	0.59	POTENCIAL HEALTH RISK	0.31	NO RISK
Cancer Center Hospital Parking Lot	0.80	POTENCIAL HEALTH RISK	0.55	POTENCIAL HEALTH RISK
Icavel Parking Lot	0.87	POTENCIAL HEALTH RISK	0.40	NO RISK
Mourao Parking Lot	0.43	NO RISK	0.32	NO RISK

Font: Author (2024)

Regarding NHO-09 vibrations have other limit values and does not use frequency to determine the axle to use but a evaluation with a simple vectorial sum using the same weightnings of ISO 2631-1 and transformed work journey. The brazillian normative classifies vibrations equal to 0.5 m/s² or lower are acceptable values which must be maintained at least. There are two intermedeary levels whose indicates different kind of corrections, the first one which in this paper is intitulated as “Potencial Health Risk class 1” demands at least

preventive actions while the second intermedeary level “Potencial Health Risk class 2” with a range of 0.9 to 1.1 m/s² besides preventive actions, require corrections on site or process to reduce the occuring vibration. These in-between levels are probable to develop health issues in long-term situation. The last range of vibrations indicated by NHO-09 is over 1.1 m/s² which will produce a health problem in the operator or driver and must be corrected. Table 5 shows the values and classifications for the different systems of vibrations measure utilized in the paper and with one decimal algarism used because the regulation require it.

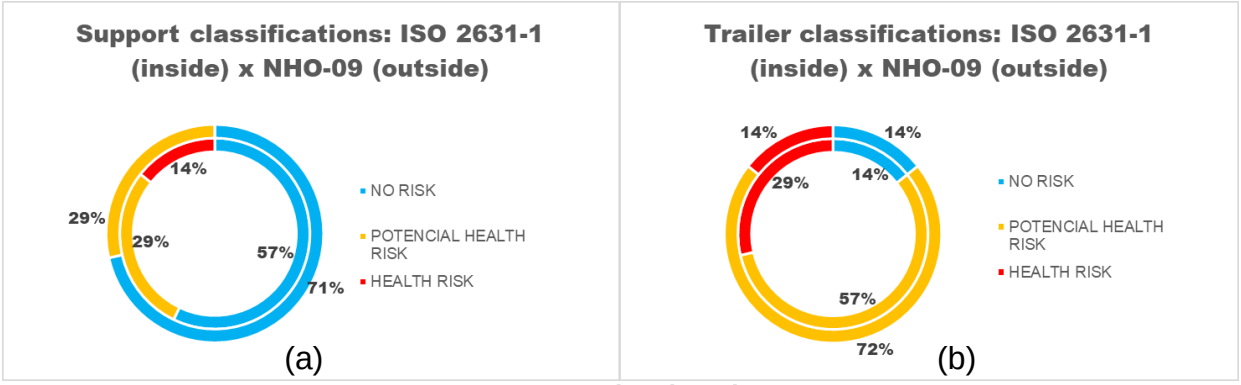
Table 5 – Final Accelerations for NHO-09 evaluation and their following classifications

Investigation site	NHO-09 trailer a(8) (m/s²)	NHO-09 trailer condition	NHO-09 support a(8) (m/s²)	NHO-09 support condition
Three Tower Street	1.1	POTENCIAL HEALTH RISK CLASS 2	0.6	POTENCIAL HEALTH RISK CLASS 1
Jordao Street	0.6	POTENCIAL HEALTH RISK CLASS 1	0.2	NO RISK
City of Lakes Events Center Parking Lot	1.9	HEALTH RISK	0.9	POTENCIAL HEALTH RISK CLASS 2
Coamo Parking Lot	0.6	POTENCIAL HEALTH RISK CLASS 1	0.1	NO RISK
Cancer Center Hospital Parking Lot	0.8	POTENCIAL HEALTH RISK CLASS 1	0.4	NO RISK
Icavel Parking Lot	0.9	POTENCIAL HEALTH RISK CLASS 2	0.4	NO RISK
Mourao Parking Lot	0.5	NO RISK	0.3	NO RISK

Font: Author (2024)

Analyzing both Table 5 and 6 is realizable that support condition values both in NHO-09 and ISO 2631-1 are no risky except City of Lakes Events center in ISO 2631-1. Comparing also the classifications of support final transformed accelerations in both regulations can reach that NHO-09 is more soft defyning the risk of vibrations. The brute results of a(8) if compared between standards also shows that all NHO-09 support results are lower than ISO’s values.Figure 7 presents donuts graphs of the percentage for each condition of standards in support (a) and in trailer measurement (b).

Figure 8 – Percentage of conditions in donut graphs: inside values for ISSO 2631-1 and outside NHO-09: (a) support system evaluation; (b) trailer system evaluation



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There is somenthing interessting to take note: the only investigation site with a diffent type of interlock a paver block (all others are type 1) is in City of Lakes Events Center Park Lot

(type 2) and it has the highest risk condition compared with other sites. It could be the type of interlocking or could be explained by extesion site as Mourao Parking lot perfomed the lowest values of a(8) on trailer vibration evaluations althought in support evaluations it would be the third place in increase sequence of lowest a(8) results.

6. Final Considerations

The first objective to be acomplished was the verification of a correlation between only RMS and vector summed trailer accelerations *vs.* support accelerations. Although the square R was considerable low some causes can be cited: it its supposed that the support system was only getting significant vibrations from its statical values when reached high speeds in the range of 40 km/h of the study, while the trailer system produced even in the start-up provided accelerations far from the inercial state. It can be validated by the Standard deviation of both system in Table 2, which are very discrepant. Future studies must observe its relation when already reached the 40 km/h limit or near limit speeds.

Regarding the values obtained by Vella *et al.*(2020) and Gomes (2015) for accelerations limits in ISO 2631-1 final accelerations cited by Mucka the results of this paper reached results near to those of Vella *et al.* (2020). Only City of Lakes events center was out of the limit indicated by the author while the other six measurements in both system attended to the limit. Something that coped it probably the speed of study which is almost equal to the one used in the paper. Other consideration is that the support values are considerable far to the limit of 1.2 m/s² indicated by Vella *et al.* (2020) which could presume that cellphones supports can not express properly vibrations felt by vehicle operator or passengers.

The conditions defined by the regulations are near in both system. NHO-09 evaluation was softer in defining an acceleration risky than ISO 2631-1 prefering to define a situation of awareness and take action on preventive and corrective procedures classified as “potencial health risk class 2”. The corrective procedures can be investigate points in the pathway which exist a pathology to be corrected whereas the preventive procedure be the determination of lower speeds due to lower speeds produces lighter vibrations as discussed before in Múčka (2022) or signals to be aware of high pavement vibrations.

Finally the arrangements to interlock paver block is something to keep studying as the result found in this paper copes to Yusuf (2024): type 1 provided better results than type 2, even better when it counted with crushed stone over it. Although there were few samples including just one of type 2 and no type 3, it is curios that the worst results to health were provided by the only pavement with arrangement of type 2.

7. References

ARAÚJO, T. C. B.; DOURADO, H. Avaliação de desempenho de pavers intertravado produzidos com rejeitos gerados nos desdobramentos de rochas ornamentais. ***Revista Eletrônica de Engenharia Civil***, v. 15, n. 2, p. 245, 2019-2020.

BUREAU OF TRANSPORTATION STATISTICS. **Transportation Economic Trends: Transportation Employment**. Available at: <https://data.bts.gov/stories/s/Transportation-Economic-Trends-Transportation-Empl/caxh-t8jd/>. Accessed in: 27 out. 2024.

CÂMARA DOS DEPUTADOS – PALÁCIO DO CONGRESSO NACIONAL (CAMARA). **Pesquisa sobre caminhoneiros autônomos mostra envelhecimento e desvalorização da categoria**. Available at: <https://tinyurl.com/2buxpu8d>. Accessed in: 27 out. 2024.

DOOCY, Shannon; DANIELS, Amy; MURRAY, Sarah; KIRSCH, Thomas D. The human impact of floods: a historical review of events 1980-2009 and systematic literature review. **PLOS Currents Disasters**, v. 5, 16 abr. 2013.

FUNDACETRO. **NORMA DE HIGIENE OCUPACIONAL 09 (NHO 09): avaliação da exposição ocupacional a vibrações de corpo inteiro.** São Paulo, 2013. 63p.

INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA (IBGE). **Em 2022, 1,5 milhão de pessoas trabalharam por meio de aplicativos de serviços no país**. Available at: <https://agenciadenoticias.ibge.gov.br/agencia-noticias/2012-agencia-de-noticias/noticias/38160-em-2022-1-5-milhao-de-pessoas-trabalharam-por-meio-de-aplicativos-de-servicos-no-pais#:~:text=Motoristas%20plataformizados%20trabalham%20mais%20horas,passageiros%20em%20sua%20atividade%20principal>. Accessed in: 27 out. 2024.

INTERNATIONAL STANDARD ORGANIZATION (ISO). **ISO 2631-1: Mechanical vibration and shock - Evaluation of human exposure to whole-body vibration – Part 1: General Requirements.** Geneve, 1997. 38p.

MAMPEARACHCHI, W. K.; GUNATILAKE, M. M. D. V. **Sustainable road construction material for low volume roads.** Disponível em: <https://www.academia.edu/7296464/A_sustainable_road_construction_material_for_low_volume_roads>. Acesso em: 28 out. 2024.

MÚČKA, P. Probability density function of whole-body vibration in passenger car. **Probabilistic Engineering Mechanics**, v. 69, p. 103311, 2022

SOUSA, V. C. Limites de vibração de corpo inteiro no mundo. **Laborare**, Contagem, v.4, n.7, p. 94-116, 2021. Disponível em: <https://doi.org/10.33637/2595-847X.v2021-90>. Acesso em: 28 out. 2024.

TAKAHASHI, D. H.; CORACINI, T. N. **Avaliação da resistência à compressão de pisos intertravados produzidos com RCD**. São Paulo, 22p.,2021. Course Conclusion Paper (graduation in Civil Enginnering) – *Universidade Presbiteriana Mackenzie, Escola de Engenharia, EE Higienópolis.*

VARKEY, E.; ABRAHAM, B.M.; SREEDEVI, B.G. Paver Tiles as Sustainable Alternative for Low Volume Roads – A state of the Art Approach. In: Two Day Online Internacional Conference on Green Highway Construction – A Sustainable Approach, Mangalore, India. **Imprint of TWO DAY ONLINE INTERNATIONAL CONFERENCE GREEN HIGHWAY CONSTRUCTION – A Sustainable Approach.** Surathkal University– NITK, 1996. p. 29-39

XIMENES, Victor. Demanda por piso intertravado cresce e fábrica no Ceará vê faturamento subir 37%. **Diário do Nordeste**, Fortaleza, 17 set. 2023. Disponível em: <https://diariodonordeste.verdesmares.com.br/opiniao/colunistas/victor-ximenes/demanda-por-piso-intertravado-cresce-e-fabrica>

YUSUF, M. Development of paving block pave structure based on type of pattern in light traffic for traffic safety and comfort. In: INTERNATIONAL CONFERENCE ON COASTAL AND DELTA AREAS, 2023, Lombok, Indonésia. **Imprint of IOP Conference Series: Earth and Environmental Science**, v. 1321, 2024.